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MECHANICAL ENGINEERING

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Leadership

Wise leadership is more essential to successful operation than extensive organization or perfect equipment.

This law has long been recognized in military affairs, having been succinctly stated by one of Napoleon's historians as: "A wise direction is of more avail than overwhelming numbers, sound strategy than the most perfect armament."

These facts so plainly recognized in military history have their exact counterpart in manufacturing. The factory and office invariably reflect the manager. His policy and direction are the deciding factors for success or failure in operation.

The application of this law replaces the autocratic management methods of driving and forcing by the democratic methods of teaching and training.

(From the Laws of Manufacturing Management, by L. P. Alford, published in this issue, pp. 301–308)

APRIL 1927

THE MONTHLY JOURNAL PUBLISHED BY THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

What does welding inspection amount to?*

SOME ENGINEERS actually believe that you can't tell whether an oxwelded joint is good or bad and that inspection of welds is almost useless. This is certainly far from the truth.

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CONTENTS OF THIS ISSUE

Laws of Manufacturing Management ... *L. P. Alford* ... 301
Power Generation in Brooklyn ... *Bert Houghton* ... 309
System Operation of Steam and Mechanical Equipment ... *H. A. Cox* ... 310
Methods of Obtaining Economical System Operation ... *H. M. Cook* ... 313
The Operation of the Hudson Avenue Generating Station of the Brooklyn Edison Co ... *W. C. Holmes* ... 321
Layout and Operation of the Electrical System of the Brooklyn Edison Co ... *E. C. M. Stahl* ... 327
Wood Lacquer Finishes (Discussion) ... 329
Better Ships for Less Money ... *G. H. Rock* ... 331
Temperatures in Powdered-Coal Furnaces Having Extended Radiant-Heat-Absorbing Surfaces ... *R. A. Sherman* ... 335
Rough Turning with Particular Reference to the Steel Cut ... *H. J. French and T. G. Digges* ... 339
The Industrial Application of Conveyor Systems ... *C. A. Burton* ... 355
Discussion of Papers Presented at Materials-Handling Session of Annual Meeting ... 356
The Generation of Cycloidal Curves ... *P. M. Mueller* ... 359
Milling-Machine Manufacturers Announce Standardized Spindle End ... 380
Work Completed on T-Slot Standardization ... 381

DEPARTMENTAL

Survey of Engineering Progress ... 361
A Review of Attainment in Mechanical Engineering and Related Fields
The Conference Table ... 373
Correspondence ... 375
A Graphical Study of Journal Lubrication; A Proposed System of Dimensioning Mechanical Drawings
Engineering and Industrial Standardization ... 378
Editorial Notes ... 382
Advisers to the State; Shifting Sands; Engineering a Modern Element of General Education; Centennials of Transportation; Pennsylvania Registration Law Nullified; Spindle Noses and T-Slots; Post-College Training
Book Reviews and Library Notes ... 386
The Engineering Index ... 389

ADVERTISING

Display Advertisements ... 1
Professional Engineering Service Section ... 138
Alphabetical List of Advertisers ... 154
Classified List of Mechanical Equipment ... 143
Opportunity Advertisements ... 153

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GEORGE H. ROCK

W. C. HOLMES

H. M. COOK

BERT HOUGHTON

E. C. M. STAHL

H. A. COX

Contributors to This Issue

L. P. Alford, editor of *Management and Manufacturing*, is a graduate of Worcester Polytechnic Institute. From 1896 to 1907 he was connected first with the McKay Shoe Machinery Co. and then with the United Shoe Machinery Co. At the end of that period he became engineering editor of the *American Machinist*, and later editor-in-chief. From 1917 to 1920 he was editor of *Industrial Management*, resigning to become editor of *Management and Manufacturing*, formerly *Management Engineering*. He is also vice-president of the Ronald Press Co. and of the Management Engineering Corporation.

* * * * *

C. A. Burton was educated in engineering at the University of Illinois and Armour Institute in Chicago and, with the exception of a year and a half during the war, has been employed continuously since 1917 as engineer and salesman of materials-handling machinery with the Lamson Co. of Syracuse and the Alvey Manufacturing Co. of St. Louis.

* * * * *

Hardy M. Cook was graduated from the Massachusetts Institute of Technology in 1910 with degree of S.B. in electrical engineering. He then entered the employ of the Brooklyn Edison Co. as a sub-station repairman. From 1912 to 1913 he was electrical superintendent for the F. M. Andrews Co., returning in 1914 to the Brooklyn Edison Co. Since 1920 he has been engineer of tests assisting in the design of Hudson Avenue Station.

* * * * *

H. A. Cox, born in Crestline, Ohio, and educated at Case School of Applied Science, has been connected with the motive-power department of the Pennsylvania Railroad and the Ballwood Co. For six years he was chief operating engineer for the Orange County Public Service Corporation, and for the past seven years has been engineer of steam operation for the Brooklyn Edison Company, Inc.

* * * * *

T. G. Digges was born in Fauquier County, Virginia. He attended the public schools of Virginia, the Virginia Polytechnic Institute, and George Washington University. Since 1920 he has been a member of the Metallurgy Division of the Bureau of Standards, Washington, D. C.

* * * * *

H. J. French, who since 1919 has been connected with the metallurgical staff of the Bureau of Standards, was graduated from the School of Mines of Columbia University. Following practical experience in the West, he became associated with an eastern automobile- and airplane-engine plant as metallurgical engineer. During the war he was engaged in metallurgical work for the Bureau of Aircraft Production.

* * * * *

W. C. Holmes, superintendent of the Hudson Avenue Station of the Brooklyn Edison Co., was graduated from Georgia School of Technology in 1913. He was then employed by the General Electric Co. in the testing department and later in the turbine commercial engineering department at its Lynn, Mass., works. He served for a year as ensign in the Navy and then returned to the General Electric Co. as turbine specialist in the New York office. Since 1921 he has been employed in the operating department of the Brooklyn Edison Company.

* * * * *

Bert Houghton was graduated from Cornell University in 1892, receiving a M.E. degree. His first position was that of draftsman and inspector with E. B. Leavitt, consulting engineer. In 1896 he became associated with Lockwood, Greene & Co., designing power plants for large cotton and woolen mills throughout New England. In 1898 he became designing engineer with the Boston Electric Light Co. and when that company consolidated with the Boston Edison Co., became construction engineer in charge of all electrical and mechanical installation work and buildings. In 1912 he was appointed assistant operating engineer with the Brooklyn Edison Co., and in 1920 was made operating superintendent for the same company, which position he now holds.

T. G. DIGGES

C. A. BURTON

* * * * *

Paul M. Mueller, manager of the lock division of the Hartford Screw Machine Co., was graduated in 1916 from Iowa State College. During the war he served in the Signal Reserve Corps of the Army and afterward was metrologist with the Pratt & Whitney Co., Hartford, Conn.

* * * * *

Rear Admiral George H. Rock, (CC), U. S. N., was graduated from the U. S. Naval Academy in the class of 1889. In November, 1890, he was ordered to the University of Glasgow, Scotland, for a post-graduate course in naval architecture preliminary to transfer from the Line of the Navy to the Construction Corps. He was construction officer, Navy Yard, New York, 1915 to 1921; manager, Navy Yard, Norfolk, 1921 to 1923; and has been assistant chief of the Bureau of Construction and Repair, 1923 to date.

* * * * *

R. A. Sherman is connected with the Fuel Section of the U. S. Bureau of Mines, in charge of the field investigation of research on boiler-furnace refractories. He was graduated from the State University of Iowa in 1920.

* * * * *

E. C. M. Stahl entered the operating department of the Brooklyn Edison Company in November, 1922, as electrical field engineer. He is a graduate of Cornell University, class of 1913, with degrees of mechanical engineer and electrical engineer. From 1913 to 1917 he was with the New York Central Railroad in the capacity of special apprentice and draftsman. After serving in the Coast Artillery of the Army during the war, he returned to the New York Central Railroad as inspector in the electrical department. In 1921 and 1922 he was with the Pittsburgh Transformer Co.

MECHANICAL ENGINEERING

Volume 49 April, 1927 No. 4

Laws of Manufacturing Management

By L. P. ALFORD,[1] NEW YORK, N. Y.

The paper is divided into two parts, the first of which discusses the laws of management in general. It is stated that the principles of management have been discussed but not generally accepted, a situation which is in contrast with the older sciences. The possible advantages of formulating the principles are pointed out and the questions are asked: What is their origin? What is their nature? What are they?

The investigation is limited to manufacturing management, inasmuch as management originated in manufacturing.

It is shown that manufacturing developed to satisfy human needs and that accepted ways for getting work done existed before manufacturing. Three such anciently accepted ways are division of labor, leadership, and incentive reward. Other accepted ways are authority with responsibility, transfer of skill, and task work. These accepted ways are the result of societal development. Such accepted ways from societal development are resistive to change, universal in application, and imperative to success, and therefore such management fundamentals are regarded as laws. The investigation shows the discovery of these laws and the determining quantitative factors for them.

Part II sets forth forty-three laws of manufacturing management, and in the complete paper these are accompanied with supporting citations.

I—ON THE LAWS OF MANUFACTURING MANAGEMENT

PRINCIPLES of management were discussed at great length during the early years of the modern movement for improved manufacturing operation and control; to such an extent, in fact, as to indicate the existence of deep interest in the discovery and declaration of the underlying rules.

But this widespread discussion and evident interest did not yield a body of fundamentals to become universally or even commonly accepted and applied. In this respect, indeed, management is still at the starting point, although the codification of methods and practice, which has taken place in recent years, points anew to the existence of ascertainable fundamentals.

This situation is in sharp and unfavorable contrast with that of the older engineering sciences, such as mathematics, physics, and chemistry, each of which has an established body of laws. These fundamentals of the older sciences are recognized as having always existed, as being natural, or God-made. They have been formulated for use by putting together the discoveries and results of the work of many scientists, investigators, and engineers. They are taught to all engineering students, and are universally applied in engineering work. The result of conformity to the truth they express has been mastery over the forces and resources of nature.

The steady accumulation of evidence points toward the establishment of management as a science, and the very complexity of its applications indicates the existence of many rather than a few fundamentals. This possibility is strengthened by the extent of the recent codification of methods and practice.

If, then, management fundamentals do exist in some number, what are they? what is their origin? how unvarying is their operation? how universal is their application? how far do they deserve our adherence?

The principal advantages to be derived from such a body of management regulatives, if and when it is developed, are obvious. When once reduced to codified form,

1 These laws may be taught to all students in engineering schools who wish to prepare for executive and managerial responsibilities

2 They may be consciously applied in every-day managerial and operating activities

3 They will form one of the foundations of the material progress of succeeding generations, and result in vastly outstripping the achievements of the present.

This paper is an investigation of the general question. It advances a theory as to the origin of management fundamentals, formulates a number of them in uniform language, and supports their importance and the extent of their application by citations from recognized leaders in management and other scientific pursuits. It is the hope of the author that further investigation will be stimulated which, in time will establish the laws of management as securely as the laws of mathematics, physics, and chemistry are fixed today.

The term "management" is so broad in meaning and implication that for the purpose of this investigation it must be restricted so that the scope of this paper may be held within reasonable limits. The author will therefore deal only with *manufacturing management*. This limitation is natural, for management, as the term is understood today, originated in manufacturing. The pioneers in management were concerned with manufacturing operations, and they are still the principal interest of the members of the Society.

Origin of Management Fundamentals

As to the origin of management fundamentals, modern manufacturing, like every other human institution, is an outgrowth of human customs. We bow to the custom of wearing clothes, hence the garment-manufacturing industry; we are accustomed to eating animal food, hence meat packing. Without multiplying such examples it is evident that the institution of manufacturing industry permits us to adopt easy, or easier, ways and means to meet the conditions and limitations under which we must live, and this adjustment is none the less real because of the difference in conditions in arctics or tropics, high altitudes or sea level, accessibility or isolation, city or country, plenty or scarcity, peace or war, and like contrasts.

As manufacturing has organized itself and been disengaged from other customs, it has come to have the foremost position in meeting living conditions and satisfying civilized needs, and is now considered indispensable to human welfare. It has been developed, however, and is still operated without much reasoned purpose. Changes and modifications have usually been put into effect to meet particular conditions and circumstances; the cases of long-time preplanning are few indeed.

When modern manufacturing began there were ready at hand traditional ways or procedures for doing work and getting work done. They represented a concurrence of belief or willingly accepted arrangements on the part of peoples. They had been proved by experience to be good practice or successful expedients. In short, they were known to be "best ways." They, and many others like them which have to do with the maintenance of the race, are called "folkways" or "mores." In these folkways we find the origin of manufacturing fundamentals.

Taken all together, they constitute the code of behavior in a society. A. G. Keller[2] points out that division of labor is one of the

[1] Vice-President, Ronald Press Company and Management Engineering Corporation. Mem. A.S.M.E.

Contributed by the Management Division and presented at the Annual Meeting, New York, December 6 to 9, 1926, of The American Society of Mechanical Engineers. Abridged.

[2] The Evolution of Man, p. 137.

most typical of these expedient ways. Two others are the exercise and response to leadership, and the incentive reward.

Other accepted ways of getting work done, which might be mentioned as equally typical, are fixing authority and responsibility, the transfer of human skill to tools and mechanisms, and the setting of task work. In fact, there are many such usages which exert a coercion on the individual to conform to them in doing work or getting work done.

These expedients are prominent among those practices which have developed modern manufacturing. But they antedated the industrial revolution by thousands of years. When that event came, they were established and ready to be used in building and separating out another great human institution.

This reasoning leads to the conclusion that fundamentals of manufacturing management, of which those considered are typical, are the outgrowth of the customs of mankind in doing work, or of common physical capabilities of mankind; in short, their origin is in societal or organic evolution. But the evolutionary process is still going on, and as new ways develop to meet new circumstances and conditions, these also can be credited to the same origin.

This theory of the origin of these basic principles has a significant bearing on our view of them. It increases our belief in their practical importance and value. It shows that they have withstood the test of centuries of application and use in human affairs amid changing conditions of every conceivable kind. It indicates that they deserve our adherence, and are entitled to adoption and use in the code of operation of manufacturing concerns.

The second part of this paper is an attempt at formulating some of these laws of manufacturing management. It presents upward of forty, arranged under some twenty-five headings. In the complete paper in practically every case numerous citations support the validity and importance of the statement offered. To all those engineers, managers, and scientists, whose experience and researches have been so freely draw upon, the author acknowledges a deep debt of gratitude and extend earnest appreciation. Without their labors stretching back so many years into the past, this paper would not have been possible.

II—CERTAIN LAWS OF MANUFACTURING MANAGEMENT

LAWS OF SPECIALIZATION

The laws of specialization are as follows:

1 Law of Division of Work or Specialization of the Job:

Subdividing work so that one or a very few manual or mental operations can be assigned to a worker tends greatly to improve the quality and increase the quantity of output.

2 Law of Division of Effort or Specialization of the Individual:

Assigning to each worker one or a very few manual or mental operations which he is particularly adapted to perform greatly improves the quality and increases the quantity of output.

Corollary: Law of Functional Management (Functional Foremanship) or Specialization of the Management:

The highest managerial efficiency is obtained by functionalizing the duties of the executives.

3 Law of Transfer of Skill or Specialization of Tools and Machines:

The attention and skill required to use a tool or operate a machine is inversely as the skill transferred into its mechanism.

4 Law of Simplification or Specialization of Product:

Concentrating upon the manufacture of a single or a few types and sizes of product tends to improve the quality and lower the production cost.

The first three laws of specialization have been commonly confused or combined in the law of division of labor. However, they are distinct. The practice of division of work seems to be as ancient as the performance of useful tasks, but the development of labor-saving machinery has come within the past 150 years, while the scientific selection of the worker and his adaptation for a particular task have had their rise in the present century.

Early considerations of the law of division of labor restrict it to manual work. However, both Babbage and Kimball have shown that mental work and effort should be included, that the fundamentals hold for professions as well as trades.

The corollary to the law of division of effort is a consequence of the specialization of the individual. Taylor[3] explains functional management by saying that it "consists in so dividing the work of management that each man from the assistant superintendent down shall have as few functions as possible to perform. If practicable, the work of each man in the management should be confined to the performance of a single leading function."

The third law of specialization is based on the concept that skill, thought, and intelligence—the ability to do—are transferred into and become fixed in mechanism so that a tool or machine through its motions can do productive work.

The fourth law of specialization, simplification, is being applied extensively in American manufacturing.

LAW OF STANDARDIZATION

The law of standardization is:

Fixing the types, sizes, and characteristics of product reduces the cost of its manufacture.

Corollary: Interchangeable manufacture reduces manufacturing cost and, all other characteristics being equal, produces a product of maximum serviceability.

LAW OF RESPONSIBILITY AND AUTHORITY

The law of responsibility and authority may be stated as follows:

Responsibility for the execution of work must be accompanied by the authority to control and direct the means for doing the work.

This law governs organization whether in the static form of functions or in the dynamic form of personnel.

Gantt declared that this law more than any other is influential in promoting the success of an organization. The system of management which he advocated was based upon it, for a man can only assume the responsibility for doing a thing properly when he not only knows how to do it, but can also teach somebody else to do it.

This law declares, on the one hand, the simple justice of accompanying responsibility with delegated authority and control, and on the other, of unavoidable responsibility for the proper execution of an order once the authority for its issue has been assumed.

LAW OF LEADERSHIP

The following is the law of leadership:

Wise leadership is more essential to successful operation than extensive organization or perfect equipment.

This law has long been recognized in military affairs, having been succinctly stated by one of Napoleon's historians as "A wise direction is of more avail than overwhelming numbers, sound strategy than the most perfect armament."

These facts so plainly recognized in military history have their exact counterpart in manufacturing. The factory and office invariably reflect the manager. His policy and direction are the deciding factors for success or failure in operation.

The application of this law replaces the autocratic management methods of driving and forcing by the democratic methods of teaching and training.

LAW OF EXCEPTIONS

The law of exceptions is:

Managerial efficiency is greatly increased by concentrating managerial attention solely upon those executive matters which are variations from routine, plan, or standard.

Graphs (curves, charts, and diagrams) have had an extensive application in manufacturing operation as a means to bring exceptions quickly and forcefully to the attention of the management.

LAWS OF THE TASK AND THE WAGE INCENTIVE

These laws are stated as follows:

[3] Shop Management, p. 99.

1 *The average worker accomplishes the most when assigned a definite amount of work to be done in a given time.* (Taylor.)

2 *An adequate wage incentive for the accomplishment of a definite task influences a workman to maintain his maximum output.*

LAW OF INDIVIDUAL PRODUCTIVITY

The law of individual productivity is:

The highest individual productivity is possible only when the worker is given the highest class of work for which his natural abilities fit him.

Taylor repeatedly stressed this law, saying its application should be a principal aim in every manufacturing establishment.

LAWS OF ECONOMIC PRODUCTION

The laws of economic production are:

1 Production at Increasing Relative Rate:

The unit cost of production decreases when the rate of increase in output increases faster than the rate of input or use of the production factors.

2 Production at Decreasing Relative Rate:

The unit cost of production increases when the rate of increase in output increases at a lower rate than the rate of input or use of the production factors.

and

The unit cost of production increases when the rate of output decreases and the rate of input or use of the production factors increases.

Church[4] defines a production factor as "any expense that has a *definite* relation to the cost of production."

These laws govern the results in manufacturing of efforts to increase at an economic cost the volume of goods needed to satisfy an ever-increasing demand. Different production policies result differently in respect to quantity and quality of the product. The total output of any given period can be increased over a former period by methods and policies which are perfectly well known, provided in a former period the methods and policies were less efficient than those now adopted. However, not all combinations and manipulations of the production factors yield a proportional increase, and in fact an actual decrease may ensue. Thus any one of three conditions may obtain: (1) Output may increase more than in proportion to the increase in the productive factors; (2) Output may increase, but less than in proportion to the increase in production factors; (3) Output may decrease. These conditions operate under the laws of economic production.

LAWS OF MASS PRODUCTION

The laws of mass production are:

1 *Large-scale production tends to increase operating efficiency and competitive power.*

2 *In large-scale production the unit time of production tends to approach the actual operating time as a limit.*

A remarkable fact in the development of manufacturing is the increase in the size of factories and industrial enterprises. The advantages of large size are: reduced cost of production, relatively smaller reserves to meet contingencies, and a stronger position in competition. The first of these is due to the greater opportunity to apply fully the laws of specialization; the second to the greater fluidity of stores of materials and tools and stocks of goods; the third to enlarged prestige, influence, and personnel ability.

LAW OF PRODUCTION CONTROL

The law of production control is:

The highest efficiency in production is obtained by producing the required quantity of product, of the required quality, at the required time, by the best and cheapest method.

LAW OF PLANNING OR LAW OF MENTAL LABOR OF PRODUCTION

The law of planning may be stated as follows:

The mental labor of production is reduced to a minimum by planning before work is started, what work shall be done, how the work shall be done, where the work shall be done, and when the work shall be done.

LAWS OF MATERIAL CONTROL

The laws of material control are:

1 *The highest efficiency in the utilization of materials is obtained by providing the required quantity, of the required quality and condition, at the required time and place.*

2 *The highest efficiency in the storage of materials, tools, and supplies is obtained by providing a definite place to store every item, keeping every item in its assigned place, and keeping an adequate record thereof.*

LAWS OF QUALITY CONTROL AND INSPECTION

The laws of quality control and inspection are:

1 *The quality of manufactured goods is a variable with an upward trend under conditions of competitive manufacture.*

2 *Control of quality increases output of salable goods, decreases costs of production and distribution, and makes economic mass production possible.*

3 *The inspection function in manufacturing (measuring and judging production) for highest efficiency must be independent of but coördinate with the functions of engineering, production, and sales.*

LAWS OF WAGES

Two laws of wages are:

1 Law of Relative Wages:

Wages tend to lower when the supply of labor exceed the demand; wages tend to rise when the supply of labor is insufficient to satisfy the demand.

2 Law of Wage Level:

The normal wage level of each country depends upon and corresponds to that country's general average productivity of labor.

LAW OF WAGE RATES

The law of wage rates is:

Wage rates on standardized jobs should never be changed except a material change has previously been made in conditions, methods, or equipment.

This is a law of good faith between employer and employee. Once accurate job standardization has been done and time and piece rates set therefrom, these rates cannot be changed without a previous change in working conditions, operations, tools, machinery, or equipment. Otherwise the morale, influence of incentives, and industrial relations are destroyed.

LAW OF HOURS OF WORK

Concerning the hours of work the law reads:

All other factors influencing production being constant, a decrease in the hours of work increases the leisure of the workers, and an increase in the hours of work increases the comfort of the workers. (Cox.)

LAWS OF ACQUIRING SKILL

The three laws relating to the acquisition of skill are:

1 Law of Speed (or Facilitation):

As the newly acquired nerve path is strengthened, the new response tends to proceed more rapidly.

2 Law of Accuracy (or Elimination):

As the new connections between impressions and memories improve, there are fewer useless and erroneous movements, the response becomes more precise and more accurate.

3 Law of Learning:

Under usual conditions an average worker acquires skill rapidly during the first half of the training period, then more

[4] Production Factors, p. 15.

slowly for a time if at all, and finally at a rapid rate until average proficiency is attained.

The first two laws are called the laws of habit formation. In the third, if the progress is represented by a curve, the period of no or little progress is represented by a flat (plateau) between two slopes.

LAWS OF HAND MOTIONS IN DOING WORK (GILBRETH[5])

Five laws of hand motions are as follows:

1 *Both hands should work and rest at the same time.*

2 *Both hands should begin and complete their "therbligs"[6] at the same instant.*

3 *The arms should move in opposite and symmetrical directions.*

4 *The paths of fast motions should be taught and learned.*

5 *The sequence of fewest therbligs is usually the best way of doing work.*

LAW OF MOTION TIME (SEGUR[7])

The law of motion time is:

Within practical limits the times required by all expert workers to perform true fundamental motions are constant.

This law was discovered by A. B. Segur and is an outgrowth of motion-study investigations. It provides means to determine the base or standard time for performing operations from the fundamental motions required, and without using either time studies or motion-picture studies. Its application within practical limits is independent of sex, job, place, or condition. By "practical limits" is meant those that usually surround the doing of work, and motions taking longer than 0.0001 minute to complete. It is not claimed that the law applies to mental work. By "true fundamental motions" is meant the therbligs classified by Gilbreth.

LAW OF DELAY ALLOWANCES (BARTH[8])

Barth expresses the law of delay allowances as:

$$P = 20 + \frac{49.5 - 0.326C}{\sqrt{0.376 - 0.0000216C_2 + h}}$$

This formula was developed by Barth from the results of several thousand observations made by Merrick, largely in the metal-working industries. It applies to fatigue and variation allowances for cycles of short duration and in connection with good time-study work. In this formula

h = estimated minimum time-study handling time for an entire cycle of operation on a job
C = percentage that h is of the entire cycle of operations
P = percentage by which h is to be increased (the allowance percentage) to give the handling portion of the total task time for the entire cycle.

LAW OF MANUFACTURING COST

The law of manufacturing cost is:

The manufacturing cost of an article includes only those expenses actually necessary for its production.

Corollary: The indirect expense chargeable to the output of a factory should bear the same ratio to the indirect expense necessary to run the factory at normal capacity as the output in question bears to the normal output of the factory. (Gantt.[9])

The three items of manufacturing cost are material, direct labor, and indirect expense. The law of manufacturing cost limits charges to a given product to:

1 Sufficient material for its production

2 Sufficient direct labor for its production

3 Only that part of indirect expense which contributes to its production.

This law is on conflict with a common theory that the cost of an article must include all of the expenses incurred while producing it, whether such expenses actually contributed to its production or not.

The determination of material and labor items is not difficult, but indirect expense is a convenient blanket to hide idleness and waste.

One application of this law of manufacturing cost is the effort to reduce idleness and eliminate waste. Methods of determining idleness, both of machines and men, and as to amount and cause, are highly developed, and the favorable effect of idleness reduction on costs is generally appreciated.

LAW OF PROFIT

The law of profit states:

A steady and reasonable profit can only come as the reward for rendering essential service.

LAW OF PLANT MAINTENANCE

The law of plant maintenance is:

Anticipating repairs and replacements prevents interruptions due to bad-order or broken-down equipment.

LAW OF FLOW OF WORK

The law of flow of work reads:

The greatest economy in progressing materials through a manufacturing plant is secured when the materials move a minimum distance in passing from operation to operation.

LAW OF DISCRIMINATION

The law of discrimination is as follows:

Sensations increase in arithmetical progression as the stimuli increase in geometrical progression. (Weber.)

This law is the basis of the theory of preferred numbers and the application of geometric series in determining proportions, sizes, dimensions, and industrial ratings. It has been proved experimentally and the least perceptible difference of intensity determined for sensations as, visual, auditory, olfactory, gustatory, tactile, kinesthetic, warmth, and cold. It is believed to hold for size and duration intensities.

LAW OF ECONOMIC LOT SIZE (DAVIS[10])

The law of economic lot size is:

The quantity of product that can be manufactured at the lowest unit cost varies directly as the square root of the preparation cost and inversely as the square root of the interest charge and storage charge.

That is,

$$Q = \sqrt{\frac{A}{K + H}}$$

where

Q = the most economic number of pieces to manufacture
A = total cost of preparation for manufacturing
K = a constant where values depend upon the ratio F of the minimum-ordering-point quantity to the theoretical minimum quantity withdrawn from stock during the manufacturing period
H = storage factor (influence of storage charges on economic size of lot).

LAWS OF ECONOMY OF LABOR-SAVING EQUIPMENT (A.S.M.E.)

The laws of economy of labor-saving equipment may be expressed by the formulas[11] developed for and adopted by the Materials Handling Division of The American Society of Mechanical

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[5] Bulletin of Society of Industrial Engineers, September, 1923.

[6] A "therblig" is an element of a cycle of motions. Seventeen are recognized: Search; Find; Select; Grasp; Position; Assemble; Use; Disassemble; Inspect; Transport loaded; Pre-position; Release load; Transport empty; Wait (unavoidable delays); Wait (avoidable delays); Rest (to overcome fatigue); and Plan.

[7] *Manufacturing Industries*, November, 1926, p. 357.

[8] Time Study for Rate Setting, by Dwight V. Merrick, p. 64.

[9] Organizing for Work, p. 34.

[10] *Manufacturing Industries*, April, 1925, p. 353, and August, 1926, p. 129.

[11] Formulas for Computing the Economies of Labor-Saving Equipment, by James A. Shepard and George E. Hagemann. Published in MECHANICAL ENGINEERING, May, 1925, p. 403.

Engineers in 1925. They provide means for economic analysis of manufacturing to show the savings that have accrued or may be secured from improved mechanical equipment.

Discussion

JOHN GAILLARD[1] and F. J. Schlink[2] wrote suggesting that consideration be given to an elaboration of the Law of Standardization along the following lines:

1 *A standard, in order that it shall raise rather than lower the standard of products, should deal with those elements or principles which are sufficiently understood and recognized to be stable. It should be concurred in by the most competent experts, so that their consensus as crystallized in the standard can be expected to control production for a reasonable period. However, a standard should deviate to the least possible extent from economical current practice, and where practices vary over a large range, effort should be made to follow the main path of common practice, if thereby economy and utility do not have to be sacrificed.*

2 *The value of a standard increases rapidly with the extent to which its provisions are based upon, and are therefore verifiable by, measurement. Therefore those elements of a standard which depend upon, or are decided by personal judgment unaided by instrumental measurement, should be reduced to a minimum.*

Corollary: The successful operation of production under standards requires the establishment of concrete means of measurement and responsibility for their maintenance, including such items as systems of testing and inspection (testing devices, master and working gages, etc.).

3 *Difficulty of arriving at a standard is increased by the number of departments of an industry or conditions of application which it must serve and satisfy.*

4 *Every standard should be subject to revision from time to time in order that it shall continue to reflect the available and applicable knowledge of the art.*

5 *Standardization focuses the attention upon the essential elements of the object under consideration and thereby transfers competition to a field where it has a positive social value.*

Jos. W. Roe[3] said that management was both a science and an art. In so far as it was a science its underlying data and laws were verifiable by measurement. In so far as it was an art it had to be evaluated by judgment rather than measurement. In so far as measurement could be and was applied to management it would be as helpful as it had been in other fields of sciences. By measurement was meant the comparison with agreed-upon standards, which might be ratios, quantities, or other bases. The essential thing was that they be generally accepted, unchangeable, and mean the same thing at all times to all concerned.

In a paper before the Society some years ago, Professor Roe had attempted to give some of the limitations and principles which applied to the use of measurement in operations of management. He believed that it could be used to test the laws of management and the operations of executives using them. He suggested, therefore, that another principle might be added to those suggested by the author: namely,

Since exact observation underlies all science, measurement, i.e., comparison with uniform standards, can be applied to such phases of management as have a scientific basis, and in so far as this is done it will aid in predicting results and in the execution of work.

Wallace Clark[4] suggested that for the two laws of specialization given by the author, there be substituted the following:

Law of Division of Labor:

As the worker restricts his field of endeavor, his product rises in quality and quantity.[5]

It had been his experience that functionalized management could not equal in efficiency non-functionalized management, unless the scattering of authority due to splitting up executive responsibilities was balanced by stronger coördination of the organization as a whole. He therefore suggested the substitution of the following corollary for the one in the paper:

As the scope of his responsibility is narrowed, the efficiency of an executive increases.

Carle M. Bigelow[6] wrote that during the last thirty years it had been fairly safe most of the time to have some excess of everything on hand, inasmuch as material prices were gradually rising. At the present time, however, with falling prices, it was necessary to limit all inventories to their absolute minimum. With this in view possibly another corollary to the laws of material control should be added, as follows:

Material inventories should be maintained at exact requirements during periods of falling prices, while speculative advantage may be taken in excess stock during periods of rising prices.

One of the outstanding reasons why scientific management had not been properly applied, even when its laws were understood and observed, had been the failure to consider the effect of each law, not upon the phase of management it primarily affected, but upon the entire management concept. Production increase beyond possibility of sales absorption, while thoroughly grounded on the laws of economic production, might easily ruin a business. It would therefore seem that, after all the other laws had been defined, there should be one final law governing their application such as:

The application of every individual law of management must be so made that it contributes its proper share to the final satisfactory composite result, and the reaction of each law on every other law should be given proper consideration.

When the laws of management were finally agreed upon and placed in definite form, some one should be given the task of preparing the proper preamble, maintaining above all else that there was a spirit or soul of management which was greater than all methods or even laws.

Ralph G. Wells[7] wrote that the author's laws of specialization, taken together with one of Taylor's laws, suggested the following corollary:

(*a*) *Clearly defined tasks, duties, responsibilities, and authority tend to increase individual and coöperative effectiveness of both management and worker.*

To the laws regarding training he suggested as an addition:

(*b*) *Clear, definite, precise, adequate instructions, based on sound, standard practice, improve both quality and quantity of output, reduce the probability of error, and promote harmony.*

(*c*) *Thorough training of employees increases their interest and effectiveness. It tends to reduce the amount of supervision required.*

The law of specialization and individual productivity suggested another corollary along the following lines:

(*d*) *Highest quality and greatest output from a given job or production center are secured when the employees are selected carefully and accurately, in accordance with predetermined job specifications.*

To the laws of planning and management effectiveness the following might be added:

(*e*) *Coördination of departmental activities through the development of comprehensive annual or seasonal manufacturing and sales programs, enforced through some form of budgetary control, secures the highest managerial efficiency.*

Also:

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[1] Mechanical Engineer, American Engineering Standards Committee, New York, N. Y.

[2] Assistant Secretary, American Engineering Standards Committee, New York. Mem. A.S.M.E.

[3] Professor of Industrial Engineering, New York University, New York, N. Y. Mem. A.S.M.E.

[4] Consulting Management Engineer, New York, N. Y. Mem. A.S.M.E.

[5] Article in *Management and Administration*, July, 1923.

[6] President, Bigelow, Kent, Willard & Co., Boston, Mass. Mem. A.S.M.E.

[7] Management Engineer, Boston, Mass.

Wise policies definitely established and thoroughly understood by the entire organization, if consistently adhered to, promote stability and permanence of management.

Somewhere in the author's summary of management principles Mr. Wells thought there should be a statement emphasizing the fact that continued success and progress in a business were dependent on frequent overhauling and checking up of all operating, management, and control methods, with a view to making possible improvements.

G. Charter Harrison[8] wrote that in stating the law of wage rates the author had said that wage rates on standardized jobs should never be changed except a material change had previously been made in conditions, methods, or equipment. Apparently he restricted the word "conditions" to mean working conditions in the shop, whereas it would seem that the law should be read to include as a change in conditions an upward or downward change in the general wage scale, reflecting a change in the cost of living.

An important law which Mr. Harrison believed should be added was the law of diminishing returns. Kemper Simpson had said that as the production was increased, and as new units of labor and capital were added, the unit cost or production was decreased. However, in almost any type of business there was a limit beyond which additional units of labor and capital could be added economically. Henry Ford, in his latest book, Today and Tomorrow, stated that when he had reached a production of 1000 cars a day and had jammed the freight facilities of Detroit he had begun seriously to examine into the wisdom of having so large a plant. His conclusions were that: "It is better to avoid difficulties than to overcome them, and not only do we find it easier to manage smaller plants, but also—which is most important—*the costs of production in the smaller plants are lower.*"

The law of diminishing returns also restricted the application of the laws of specialization, of planning, and of quality control and inspection.

Prof. Henry Ludwell Moore, in his Laws of Wages, stated two laws of wages which might be added to those given by the author, as follows:

1 *That the more rapid the increase of capital in the industry, the more rapidly do wages increase.*

2 *That the fluctuations of wages about their general trend are inversely correlated with the machine power with which the laborers work.*

Lillian M. Gilbreth[9] wrote that two things in the paper might well be emphasized. The first was the need for accurate measurement. The second was that there was need to realize the broad scope of possible application. The author had been careful to say that while he believed the laws were as stated, there was always room for improvement. For example, speaking of the learning process, he said: "Under usual conditions, an average worker acquires skill rapidly during the first half of the training period, then more slowly for a time if at all, and finally at a rapid rate until average proficiency is attained." It should be said that under unusual conditions even an average worker might avoid a plateau, and under usual conditions a worker above the average might avoid one. The upper boundary was not set, and the room for improvement was practically limitless.

It was to be hoped that these "laws of manufacturing management" might be extended into papers on laws of office procedure, selling, etc. In such papers would be included a new field for management, that of the home. A start had been made in the application of management to this field, and while American engineers so far did not seem to take the work seriously, the feeling in Europe was that the application of management must be extended into the home if waste elimination was to be properly carried out.

Carl G. Barth[10] wrote that he did not share the author's belief that the laws of management might be established as securely as were the laws of mathematics, physics, and chemistry, except perhaps in that field of management which dealt with materials and machinery. In the field which dealt with human problems numerous helpful rules and principles might undoubtedly be established and made into a code for general guidance; but these could never possess that rigidity which would properly make the term "law" applicable to them.

One the other hand, some of the "laws" formulated by Mr. Alford were of such a self-evident nature that they should be designated axioms rather than laws of management, while some of them were indeed debatable. The law of wage rates had been misstated in the usual way. It was not the wage rate that should never be changed, as stated, but the production time on which the wage rate was based. Wage rates on standardized jobs were subject to the same fluctuation as were day wages. Another "law of wage rates," in the sense used by the author, was also that wage rates must be based on such simple mathematical rules that the worker would have no difficulty in determining, unaided, the money he earned in doing a job.

Under the law of delay allowances the author gave the empirical formula developed by Mr. Barth from data submitted by Dwight V. Merrick. While this formula had been used quite successfully by Mr. Merrick and others, it certainly was not of a nature that justified its being elevated to the dignity of a law. It should be given, if at all, in a possible special group of empirical or tentative laws. Neither was the law of manufacturing cost as formulated by Gantt a law, but merely a choice of policy, the propriety of which Mr. Barth, for one, was always ready to dispute.

It would therefore seem that a better title for that which Mr. Alford had had in mind when he had undertaken the preparation of his paper would be, say, A Code of Axioms, Laws, and Principles for the Guidance of Industrial Managers.

C. W. Beese[11] wrote that in any manufacturing problem there was a point of maximum economy, the location of which might be calculated with respect to the quantity of product to be produced. At this point the predominance of the effects on cost of these two opposing factors transferred from one to the other. The production of a smaller quantity of goods by methods of interchangeable manufacturing would be less economical, owing to the fact that the saving in direct labor charges would not offset the increased costs of special tools. At a higher rate of production the reverse was true. It should be clear that the aim of the manufacturer was the ultimate economy, and that considerations of cost and convenience to the consumer of a product might warrant an increased cost of manufacture in order to attain the advantages of interchangeability.

Leonard M. Kuvin,[12] commenting on several of the laws stated, wrote that the number of hours of work in industry was taken to be the number at which there was a balance between comfort and leisure, when all other factors influencing production were constant. This law silently assumed, first, that comfort and leisure were independent of each other, and, second, that all other factors could be constant. The general average of industrial workers thought neither of comfort nor leisure nor the product of the two when their work day was too long for their endurance; they were concerned merely with animal rest.

The length of work day in any industry at any time was a function of: (*a*) The nature of the work, monotony, noise, etc., and physical wear of the body of the worker; (*b*) competition within the industry at home and abroad; and (*c*) the relative productivity of the industry and others in the country.

The laws of task and wage incentive as given in the paper dealt only with the wage incentive. When it was considered that nonfinancial incentives were as great as, if not greater than, wage incentives, it seemed wrong not to include them in a body of laws on management.

J. A. Brown[13] wrote that he believed that the paragraph dealing with laws of economy of labor-saving equipment should be subjected to more critical scrutiny both as to its scope and subject-matter.

John Maurice Clark, in speaking of the general law of mechanical improvement, had said: "The general rule governing all such questions of policy may be put in this form. Most labor-saving

[8] Stevenson, Harrison & Jordan, Management Engineers, New York, N. Y.
[9] Chief of Staff, Gilbreth, Inc., Montclair, N. J. Mem. A.S.M.E.
[10] New Haven, Conn. Life Mem. A.S.M.E.
[11] Head of Department of Industrial Engineering, Pennsylvania State College, State College, Pa. Assoc-Mem. A.S.M.E.
[12] Index Number News Service, New Haven, Conn. Jun. A.S.M.E.
[13] Mechanical Engineer, Brooklyn, N. Y. Mem. A.S.M.E.

devices of a mechanical sort call for an investment in some sort of machinery or equipment and by means of this investment the labor costs of the operation can be reduced. The quantity and quality of equipment which it pays to install depends on the amount of use that will be made of it."

John M. Williams several years ago before the Taylor Society had stated that there were two conflicting elements of cost, the confusion of which was at the bottom of a large part of our business troubles. These were variable cost, or that part of cost which varied in proportion to the volume of business done; and fixed cost, or that part of cost that existed irrespective of the volume of business done. If we were consistent in dividing *all* our costs into the foregoing elements, he said, we found the whole problem of administrative accounting wonderfully simplified.

Was there, Mr. Brown asked, any better basis for comparing costs than on that of the total annual cost? Was there any better functional grouping of cost elements than as variable cost and fixed cost, or as some writers preferred, controllable and non-controllable expense?

Robert T. Kent[14] wrote that there might be some difference of opinion regarding certain of the laws that the author had compiled. Some of them admittedly were of controversial character. Without question, they were incomplete. Nevertheless, taken as a whole they were a distinct addition to the literature of management, and as such were bound to have widespread effect. It was with one or two of these effects, rather than with the laws themselves, that Mr. Kent wished to deal.

The formulation of these laws, he wrote, should have a profound effect on the teaching of management in the colleges. A comparison of the courses offered by several schools a few years ago had revealed a rather imperfect understanding on the part of those laying out the courses of what management really was. They emphasized the system and the routine, as exemplified in those institutions that had come under observation, and neglected to a considerable extent the basic principles of management. Most of them had laid great stress on time study, whereas time study was one of the minor phases of management. They had seemed to have no common objective, nor a common starting point. With the presentation of laws that could be tested and verified in the same manner that the laws of physics and chemistry were tested, management could be taught in the same manner as any other science. If these laws, and those that would follow them, were made the basis of courses in management engineering, the schools would be on a solid foundation and would be able to render even greater service to industry than they were now rendering.

Another field in which these laws should have a marked effect was in industry itself. The laws formed a most convenient foot-rule by means of which the manager could measure the work of any department, and, what was more important, his own work. If, after reading each law, he asked himself whether or not that law was being applied by him, and if so, how effectively it was being applied, he would get a view of his work that would amaze him. Leaks that should be stopped would become apparent. Departments that were weak and needed strengthening would stand out. The entire business would benefit by such a survey. Thus used, the laws would become a most useful tool in industry, and not a mere statement of abstract principles.

B. A. Franklin[15] wrote that one of the most important elements in management was organization, and a very important element in organization was promotion. Eventually there would be made certain laws or organization, and certain laws of promotion within the organization.

Harold V. Coes[16] wrote that the author had advanced the cause of intelligent management in manufacturing by codifying for the first time the laws pertaining to and underlying the present nebulous science of management. The prime reason that had tended to prevent the formulation of the science of management was the fact that management, in a broad sense, utilized something from nearly all the sciences. This had tended to confusion and loose thinking, with a distortion of values and warped perspective.

We should make certain that what we termed a law of management or a fundamental principle was, in effect, peculiar to the science of management, and not a law that had been deftly borrowed from some other science and dressed up for the occasion.

Mr. Coes laid stress upon the desirability of doing this, for the reason that one frequently found among able managers and executives a surprising supreme contempt for some of the things that had been brought into management from some of the other sciences, such as applied psychology, and again, some of the things that had been brought to our attention by medical science. Hence he felt that the cause of management would be decidedly advanced if some one, properly qualified and competent, could show the relationship of management to the other sciences and the actual indebtedness of management to these sciences.

John Younger[17] wrote suggesting that management be divided into its two functions, human and mechanical, the latter term being used for the want of a better one. We had gone far in our understanding of the mechanical phase, the side that the manager used, but we were still on the threshold as regarded the understanding of the human side.

It seemed to Professor Younger that there should be a further discussion of the law of individual productivity. There was a growing tendency to add more and more unskilled workers to operating forces. As a converse of this law, therefore, it might be said that *it is advisable in a particular job to use the least-skilled workmen that are capable of doing the job.*

The principle that inspection must be independent of production was also open for further discussion. Preventive inspection had become such a force today that it should be recognized. Preventive inspection was distinctly a part of production and should not be separated from it.

G. S. Radford,[18] in a written discussion, said that every failure to obtain the best economy of manufacture could be traced to the violation in some degree of one or more of these fundamentals. Yet how few industrial operators had a complete grasp of them—a situation that was doubtless traceable to the fact that hitherto there had been no convenient place to find them collected for use without considerable hard reading.

The author had suggested the use of the fundamentals in the code of operation of manufacturing concerns. Would it not be a suitable piece of constructive work for the Management Division to prepare such a code to be issued with the Society's endorsement and approval? Each principle in such a code necessarily would be accompanied by a clear explanation of its meaning and practical application. Needless to say there should be a warning to the effect that these basic principles were interrelated and must be used as guides rather than rules—therefore judgment always must enter to determine to what degree any one law could be given scope without interfering with the proper application of the others.

Ralph G. Macy[19] asked whether the author had stated the forty-odd laws in the order of their importance, and whether he meant to infer that the laws stated first were most important.

W. N. Polakov[20] wrote that the author had assembled in a most interesting and instructive way a series of doctrines that were differently termed fundamentals, or laws, or principles. Some of these principles were subject to question; some, perhaps, were not. All, in Mr. Polakov's opinion, should be reclassified. Some doctrines were evolved from practice and experience and others from assumed postulates. Before the paper could be codified, these postulates would have to be detected and tested from the point of view of whether or not some of the doctrines were based on false postulates and others on postulates that were true. When this work was done, some of the doctrines would appear conflicting, some meaningless, and the remainder would be fortified and might form a body of doctrine sufficiently established to be codified and used for such purposes as the author hoped they would be.

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[14] Superintendent of Prison Industries, State of New York. Mem. A.S.M.E.

[15] Vice-President, Strathmore Paper Company, Mittineague, Mass. Mem. A.S.M.E.

[16] Vice-President and General Manager, Belden Manufacturing Co., Chicago, Ill. Mem. A.S.M.E.

[17] Professor of Industrial Engineering, The Ohio State University, Columbus, Ohio. Mem. A.S.M.E.

[18] Consulting Engineer, New Canaan, Conn. Mem. A.S.M.E.

[19] Consulting Engineer, New York, N. Y. Mem. A.S.M.E.

[20] President, Walter N. Polakov & Co., Inc., New York, N. Y. Mem. A.S.M.E.

Author's Closure

The author, in closing, said that the spirit in which his paper had been received and discussed was a source of sincere gratification. Seemingly there was complete agreement with the thought that a group of management fundamentals, such as the paper suggested, could be formulated and declared. Indeed, seven of those who had taken a part in the discussion had offered eighteen other laws to be included in a more complete code than the one presented in the paper.

Several suggestion were offered by way of modification and changes of the laws as given. The most of these were elaborate and a conclusion could only be reached by a consensus of opinion. However, the objections offered to the law of wage rates by Messrs. Harrison and Barth were well founded. A better phrasing was:

> *Base time on standardized jobs should never be changed except a material change has previously been made in conditions, methods, or equipment.*

In this form it might be considered a corollary to the law of motion time.

The author heartily concurred with the following comments and suggestions made during the discussion:

The need of a preamble to declare above all else that there was a spirit or soul of management which was greater than all methods or even laws (Bigelow); the axiomatic nature of some of the fundamentals which raised the question as to whether they were laws (Barth); the need of accurate measurement to prove or disprove the findings (Mrs. Gilbreth); the possible effects of the laws on the teaching of management and in the operation of industry (Kent); the relationships of these laws to the fundamentals of other sciences (Coes); the interrelation of these laws in any scheme of management and the need of exercising judgment in their application (Radford); the preparation of a "code of operation of manufacturing concerns" by the Management Division to be issued with the Society's endorsement and approval (Radford).

Mr. Macy had asked if the laws as presented were in the order of their importance. No attempt had been made to establish such an order; rather, they had been roughly grouped according to topic, as Mr. Macy had pointed out.

Stock Ownership by American Wage Earners

MODERN machine production, to which we owe most of the material progress we have made since the beginning of the nineteenth century, has brought some troublesome by-products. One of these is the separation of the laborer from ownership of tools and plant. This, taken together with other developments such as minute subdivision of processes, has resulted in a noticeable decline in craftsmanship and in interest in the job, and has led to a need for new incentives. Industry and society are facing the problem with no thought of a backward step. A return to the methods of bygone days is unthinkable. Instead, we see now, with increased production and increased earnings of labor, a tendency toward diffusion and democratization in the ownership of the plants and machinery to which the worker is bound by the very nature of his job.

This diffusion of ownership has given impetus by the practice of many corporations of selling their stock on favorable terms directly to their employees. The industrial relations section of Princeton University, in a recent study carried out under the direction of Dr. Robert F. Foerster, found that the employees of more than two hundred reporting companies own or had subscribed for stock worth more than $700,000,000. It is likely that if full reports could be secured the holdings of employees in the stock of their own corporations would fall not far short of a billion dollars.

Stock participation by labor probably would not have been thought of but for the unexampled prosperity of the American worker. The wage earner has shared in the vastly increased productiveness of industry so that he not only has the purchasing power by which that productiveness to a great extent is maintained, but often has a surplus for saving.

The employer not only is interested in helping the wage earner invest the surplus he has happened to accumulate, but he wants to encourage him to save still more. To this desire to encourage saving and investment there often is added a purpose to promote interest and loyalty through the wage earner's feeling that he is a partner in the enterprise and a part owner of the company.

In a few companies employees already own a majority of the stock; in others, a substantial minority. Mathematically, it is quite possible that in the not distant future many of the large corporations in the country may be owned mainly by the people on their payrolls. But this result, if it comes, will not necessarily mean a change in control. It is perfectly well understood that management in the typical large concern is practically self-perpetuating so long as it is reasonably successful, and that it need not represent ownership of more than a respectable minority of the stock. Control of industry by labor, if it should ultimately come through the slow and enlightening process of saving money and buying shares, would not involve anything particularly alarming. It might, in fact, be beneficial. However, it seems unlikely that this control will be attained in any period immediately in prospect.

The rapid increase in the number of small investors, many of whom are not troubled by surtaxes on their incomes, may be expected to result in an increasing pressure for dividends. This pressure will scarcely be ignored by boards of directors, especially if much of it is exerted by stockholders who are also employees.

But the reaction between small stockholders and controlling management will scarcely be all in one direction. As directors become more sensitive to the opinion of wage earners and investors, it is to be expected that the latter will acquire a greater knowledge of and sympathy with the problems of business and a better understanding of economic truths. Exactly this thing is happening.

Whatever may be the effect of this knowledge and understanding upon the psychology of the employer, there is little room for doubt that upon the mind of the worker it has been a steadying and conservative force. The American workingman is not usually radical. Still less is he likely to be radical when he is informed upon the facts of business and especially when he feels himself a financial sharer in the prosperity and adversity of industry.

There are, however, real and serious dangers. Most grave of all is the danger that workingmen will be encouraged to put their savings into securities of doubtful or speculative value. It is probable that comparatively few corporations ought to offer their common stock to employees. Especially is this caution needed in a period of generally high stock prices. To offset this danger there are alternatives and safeguards, applicable to some companies, which must here be passed by for lack of time.

Another danger is that of too much persuasion. High-pressure salesmanship should have no part in an employees' stock campaign. Another pitfall to be avoided is that of unwise confusion of stock participation and profit sharing. Lastly, there is the danger of so administering a stock plan that workmen are taught things about economics that are not true. It is so easy to give the wage earner a partner's share in the profits of industry without giving him a partner's share in the responsibilities. It is easy, for example, to guarantee the price of a stock or to insure the buyer against loss through declining markets—and when we do that we are destroying about 50 per cent of the good effects of stock ownership. On the other hand, there is the temptation to sell stock "with a string to it," and deny the purchaser the very rights he is supposed to have acquired.

Stock participation is not suited to all companies or to all circumstances or to all types of employees. Too rapid growth, involving unsafe schemes or ill-advised risks, would not be good for business or for society. But if wisely planned and administered and confined to the companies to which it is adapted, stock participation offers a powerful instrument for reducing waste of labor in industry.—Edward S. Cowdrick in a paper presented at a joint meeting of the Management Division and the Metropolitan Section of the A.S.M.E., New York, October 26, 1926.

Power Generation in Brooklyn

Capacity of the Brooklyn Edison Company's Stations and Extent of the Territory They Serve—Organization of Operating Department and Attributes Required in Its Personnel

By BERT HOUGHTON,[1] BROOKLYN, N. Y.

BEFORE taking up the subject of power generated in Brooklyn I should like to speak of the borough's increase in population and manufacturing industries. Brooklyn covers 81 square miles and in 1925 had a population of 2,204,000; an increase of 200,000 in five years. It is the third largest manufacturing city in the United States.

Some of the largest industries are the manufacturing of boots and shoes, food preparations, furniture, and clothing, also an extensive business in finished marble, slate, and stone.

These manufacturing industries have increased their business over two billion dollars since the 1920 census.

This increase in population and manufacturing industries requires electric energy to be delivered to them at a reasonable price.

The Brooklyn Edison Company has anticipated this demand and installed each year larger and more efficient mechanical and electrical equipment. Over 875,000,000 kw-hr. was generated in 1926. The company's business has doubled every 4½ years since 1903.

To supply this energy the Brooklyn Edison Company has three generating stations:

	Kilowatt capacity
66th Street Station	65,000
Gold Street Station	125,000
Hudson Avenue Station	230,000
Total	420,000

The ultimate capacity of Hudson Avenue will be over 700,000 kw. alone.

The power generated in these stations is distributed to customers through 17 direct-current substations and 11 alternating-current substations.

There are 53 large power customers taking current direct from the generating stations, some individual customers using over 5000 kw.

A map of the city showing the location of these generating stations and substations, and also a system operator's chart giving the feeder distribution between generating stations, substations, and power customers, and the tie feeders with other companies are given in another paper of this group.

To carry out the work of the Operating Department, I would like to say a word about its organization. It consists of six bureaus, as follows:

The System Operating Bureau directs the operation of the electrical system, which includes the care and operation of the electrical equipment in the generating stations and that of large customers, dispatches the load from the generating stations to substations and large customers, is responsible for the safety measures on all high-tension feeders and equipment, and keeps a record of loads generated and distributed.

The Steam Bureau is in charge of all steam and mechanical equipment in the generating stations, the Rossville coal-storage yard, and the steam heating plants. It is the duty of this bureau to have a sufficient number of boilers and turbines in readiness to meet our varying load conditions.

During the early morning hours our production is relatively low, about 50,000 kw., whereas during business hours we must supply in the neighborhood of 160,000 kw. and at five o'clock in the winter we must supply 260,000 kw., or over five times as much as during the early morning hours.

Our daily loads may be nearly the same for several months, but every now and then a thunderstorm comes up suddenly, increasing our load over 60 per cent and requiring more boilers and turbines to be put into operation immediately.

The Substation Bureau has charge of the operation and care of the substations throughout the city. It maintains a continuous service at the substations and keeps the proper bus pressure to supply the correct voltage to the mains.

The Test Bureau is responsible for obtaining, regulating, and analyzing engineering data for operating purposes, and conducts tests on steam and electrical equipment which are required for the efficient and reliable operation of generating and substations.

This Bureau makes regular reports to the Operating Superintendent of comparisons of station efficiencies, turbine performances, boiler performances, and the efficiencies of the auxiliary equipment. It maintains a regular inspection service covering the chemical analysis of coal, ash, oil, feedwater, and boiler water. It maintains a crew of men to look after all station instruments. The station-betterment crews of this Bureau are continually checking station instruments and taking care of the technical maintenance of the equipment.

The Battery Bureau has charge of the care and maintenance of all batteries on the system—both generating and substations.

The Office Bureau has charge of all the clerical details of the department, the keeping of all the department records and statistics.

Attributes Required in Personnel of the Operating Department

Nowhere in our organization are the basic qualities of reliability, obedience, honesty of purpose, punctuality, spirit of coöperation, and quick judgment more essential than in the man who operates our stations. No man is suited to be an employee in a generating station or substation unless he is mechanically inclined and enjoys finding out how and why the equipment works in a certain way, and how he can control any peculiarities of the machine or equipment. An employee in either a generating or substation must not make mistakes; a wrong valve closed or a wrong switch thrown might mean a serious shutdown.

To promote these qualities among the men, provisions for educating and training them have been made whereby courses of instruction are given by division heads.

The work covers the generation of power from the coal pile through the different stages and delivering it in electric energy to the customer. It also includes the operation and care of the equipment, and outlines the steps to be taken for promotion.

These courses tend to stimulate and create an inquiring mind among the men, giving them courage to work harder for their personal advancement.

During the construction of Hudson Avenue Station, men were brought in from the different bureaus of the Operating Department, and these men followed the work in detail. The knowledge they gained during construction accounts for the satisfactory starting and operating this station. This system of promotion not only applies to Hudson Avenue but to work being done in all the generating and substations as well.

The Operating Department is bringing about economies by keeping the men in good health, contented, and happy. Men working under these conditions accomplish more. These men take great pride in keeping the equipment in their charge in good repair, clean, and in the best operating condition. This means that the men not only have to be skilled in operating but in making repairs, both mechanical and electrical.

The operating force must thoroughly understand the unusual symptoms of system disturbances, and be able to manipulate the equipment and the distribution of the load in emergencies.

The operating personnel must possess cool judgment, the ability

[1] Operating Superintendent, Brooklyn Edison Co. Mem. A.S.M.E.

Presented at a meeting of the Metropolitan Section of the A.S.M.E., New York, January 31, 1927.

to decide quickly what to do in emergencies, and be self-possessed in the face of unusual occurrences, and even personal danger.

OPERATING PERFORMANCE

It is the operating policy of the Brooklyn Edison Company to have sufficient equipment of all kinds in service so that if any essential piece of equipment, particularly a main turbo-generator, should become disabled, the remaining equipment in service will have sufficient capacity to carry the load.

It is the variable demand on our production which creates the difficult problem of maintaining efficient and economical operation. If we could carry a constant load 24 hours a day and not be called upon suddenly to exceed that constant load, our problems would be greatly simplified.

The basic problem of the Operating Department is to turn out and deliver without interruption to our customers a kilowatt-hour for the least amount of money spent in labor and material. Even when the finest and most efficient equipment is installed, there is still a very wide range in cost within which this equipment may be made to produce a kilowatt-hour.

Proper care of the equipment to prevent waste of heat and materials is of fundamental importance and is carried on continuously with painstaking care.

Having given you the foregoing perspective view of the territory we serve and our fundamental problem, I am going to turn over the details of how we accomplish our results to the men who are directly associated with the work.

System Operation of Steam and Mechanical Equipment

Division of Load—Selection of Fuel—Operation Changes—Maintenance Procedure

BY H. A. COX,[1] BROOKLYN, N. Y.

SYSTEM operation of generating equipment on our system is based upon the load available for each station and the relation that each station bears to the system. The plan of operation that results in the lowest cost of production is predicated upon station designs, available fuels, load division, condition of equipment, and operating factors.

The system load, 25- and 60-cycle, is divided among three generating stations, Hudson Avenue, Gold Street, and 66th Street. Due to the growth of our 60-cycle load a new station, Hudson Avenue, was placed in operation during the early part of 1924. The first unit, a 50,000-kw. turbine with two-point bleed, and four boilers, was placed on the bus in May of that year. The second and third units, each the same capacity, were completed in July and October of the same year. The steam conditions were 300 lb. pressure and 200 deg. superheat. In 1925 an 80,000-kw. unit with four-point bleed was purchased for 400 lb. steam pressure and 225 deg. superheat. Four stoker-fired boilers, water-screened on three walls and with air preheaters, comprise the steam-generating equipment for this unit. This fourth unit, a description of which is taken up in another paper, was placed in operation September 30, 1926.

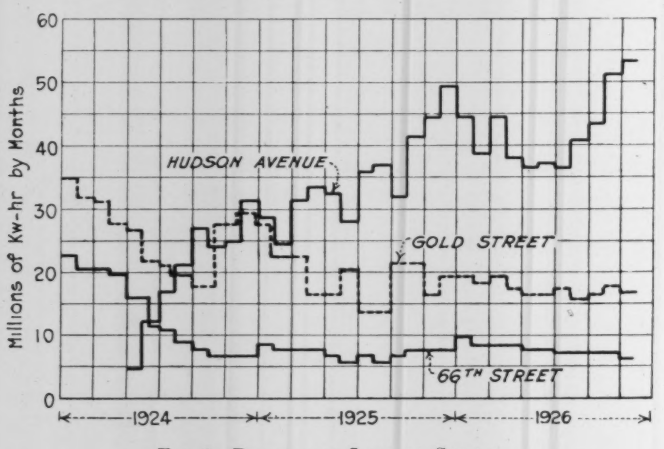

FIG. 1 DIVISION OF LOAD ON SYSTEM

Gold Street, the 25-cycle station, is equipped with 6 units ranging from 11,000 to 30,000 kw. Forty-eight small boilers with low settings and short stokers supply steam at 200 lb. and 100 deg. superheat. Station auxiliaries are quite evenly divided between direct-current motors and steam-turbine drives.

The 66th Street Station, situated on the Bay Ridge waterfront, was built in 1897 and rebuilt in 1918 into what we now call our first 60-cycle plant. One 15,000-kw. and four 12,500-kw. turbo-generators—in all 65,000 kw.—comprise the main generating equipment. When the station was rebuilt twenty-four 500-hp. boilers were raised, modern settings installed with 5-retort clinker-grinder stokers, and in 1921 eight 760-hp. boilers were installed in a new addition to the old boiler house. These stokers were 8-retort, 23-tuyere, with single-roll crushers. During 1924 automatic combustion control was applied to these units, and the resultant boiler efficiency of this section of the station compares very favorably with the first installation of boilers in Hudson Avenue.

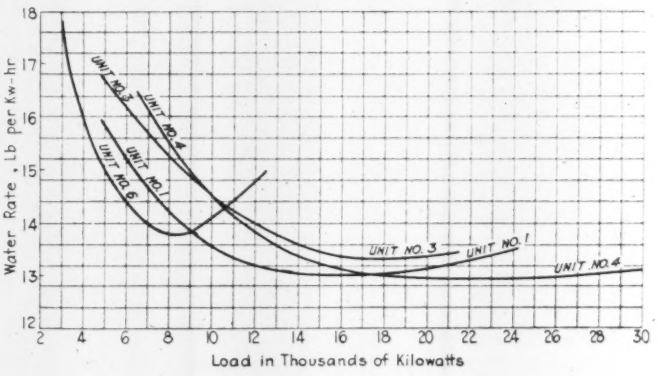

FIG. 2 COMPARATIVE WATER-RATE CURVES OF UNITS 1-6, INCLUSIVE, GOLD STREET STATION

(Referred to 185 lb. per sq. in. gage pressure, 100 deg. fahr. superheat, and 28.5 in. Hg vacuum.)

SELECTION OF FUEL

Conditions governing the choice of fuel are so numerous as to scarcely be worth detailing, yet a few points such as storage, allocation to stations, and the mixture used on the stokers are of interest. We maintain a coal supply of 50,000 to 75,000 tons in storage at Rossville, Staten Island. Since 1919 a study has been carried on with reference to the storage characteristics of various grades of coal, and some limitations in methods of piling were imposed by the machinery already on the location. At times three grades were on the ground at one time, piled in various ways and depths up to 35 ft. As a result of these studies we have found that out of ten coals stored only one can be carried on the ground for two years or more without undue waste or depreciation.

Within certain limits, the chemical analysis of a coal is rather an indefinite guide as to the actual results that may be expected

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[1] Engineer of Steam Operation, Brooklyn Edison Co. Mem. A.S.M.E.

Presented at a meeting of the Metropolitan Section of the A.S.M.E., New York, January 31, 1927.

in stoker operation. An analysis of the ash will add somewhat to the general information, but even this is insufficient. In order to obtain the maximum of efficiency and the minimum of maintenance the physical characteristics of the coals must be thoroughly understood, and to the best of our knowledge this can only be determined by trial. With furnaces, boiler settings, and stokers of varied types as well as design, it is obvious that of the fuels available one or two classifications may be more suitable for operating than other grades. At Gold Street we use a short-flame, free-burning coal with excellent coking characteristics, having a low ash content with

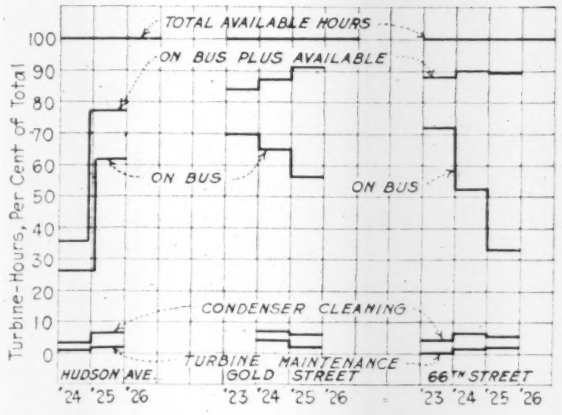

FIG. 3 TURBINE OPERATING RECORD

a high fusion point. The coal consumption of 66th Street is relatively small so that barge demurrage bears some weight, but since one contractor can supply his fuel in small barges, this arrangement fits in nicely with automatic combustion control and renders the boiler-room operation at the station extremely simple and efficient.

Three grades of coal then remain to be used at Hudson Avenue. When the station was first placed in operation these three classifications were unloaded into any bunker. Some prize clinkers resulted, with attendant high combustible in the ash, poor boiler efficiency, and high stoker maintenance. A systematic study of fuel feed and air control did not correct the difficulties. The bunkers were then emptied and the grades kept separate and detailed study made of each. One coal gave an excellent performance. Another would not coke, "popcorned" to the clinker pit, and clinkered severely. The third formed a mat over the stoker that was almost impervious to air pressures under 3 in. Almost as a last resort the last two grades were mixed in the coal lorries on a half-and-half basis. This mixture solved the problem as each appeared to supply that characteristic needed by the other. This plan of separate bunkers and mixing of two grades in the lorries is still being carried out.

OPERATION CHANGES

When Hudson Avenue and the 35,000-kw. frequency changer were placed in commission, a change in the operation of Gold and 66th Street Stations was made necessary. Previously each station had been operated more or less as a separate unit, having its own reserve turbine and boiler capacity. With one 25-cycle and two 60-cycle stations together with a 35,000-kw. tie feeder, the only performance that could be justified was the plan of operation that would result, not in the most creditable showing at Hudson Avenue, but rather in the minimum coal or B.t.u. required for a system kilowatt-hour and the lowest total generating cost of a system kw-hr.

Spare capacity is carried in each station, dependent upon the system load and units available, but the major portion of the reserve devolves on the two older stations. We reckon station and reserve capacity in terms of boiler capacity. For example, sufficient turbine capacity may be on the bus, but lacking the ability to supply steam for this rating in an emergency the reserve is soon depleted. Still further, having sufficient boiler capacity on the headers for an emergency, a fairly definite relation exists between the load carried and that which the station can pick up.

The Gold Street turbines have widely different characteristic water rates, and the loads carried exert a wide influence upon the station economy. The boilers are held steaming at ratings that can be doubled in an emergency, and the station carries more load than is dictated by physical characteristics alone, due to the size of the 25-cycle load. The 66th Street units of later design have similar water-rate curves, so that load division is not quite so important. Better performance is obtained at this station since one unit has a bleed connection and 8 boilers in the south boiler house have efficiencies at least 5 per cent higher, and due to combustion control boiler ratings can be varied between 80 and 325 per cent.

All of our stations are located adjacent to large trunk sewers, consequently with every flood tide the condensers become fouled. Up to the present time we have found rubber plugs and hot water

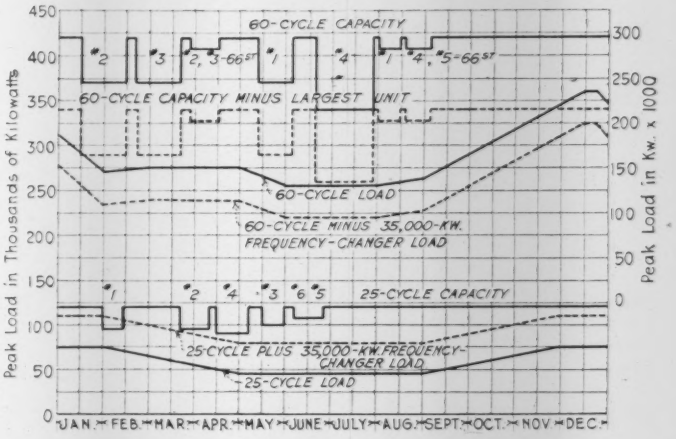
60-CYCLE CAPACITY
60-CYCLE CAPACITY MINUS LARGEST UNIT
60-CYCLE LOAD
60-CYCLE MINUS 35,000-KW. FREQUENCY-CHANGER LOAD
25-CYCLE CAPACITY
25-CYCLE PLUS 35,000-KW. FREQUENCY-CHANGER LOAD
25-CYCLE LOAD
Peak Load in Thousands of Kilowatts
Peak Load in Kw. x 1000
JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC.

FIG. 4 TURBINE SCHEDULE FOR 1927

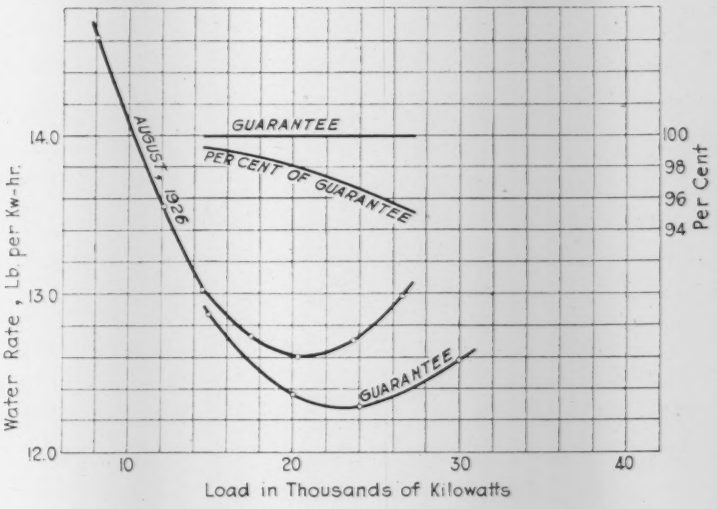

FIG. 5 WATER-RATE CURVES, UNIT NO. 4, GOLD STREET STATION
(In service Oct., 1917; kilowatt-hours generated, 949,000,000; hours on bus, 59,000.)

to be the most effective cleaning method. As an example of the stress we place on this work, 0.1 in. vacuum on one of our units between 27½ and 28 in. with 66-deg. circulating water is equivalent to 10 deg. in the feedwater, 20 deg. in steam temperature, 0.62 per cent in boiler efficiency, 20 deg. in flue gas, and 5½ per cent in excess air. Testing for tube leakage is all done with fresh water taken from a storage tank and returned to the same tank by the hotwell pumps. This enables us to keep the condensate in the heaters at all times, and as a matter of fact, due to the care exercised we have not thrown the condensate overboard in any of our stations during the past two years.

MAINTENANCE

Considerable space has been taken up in the technical press by discussions of plans used in systematic conditioning of station equipment, and each writer appears to have lost sight of the fact that maintenance has its origin in operation. Every system appears to be completely wound up in red tape that is either

certain to become tangled up at times or soon become so automatic that the apparatus depreciates. It is quite possible to catalog some equipment and assign arbitrary schedules of inspection, but if this is broadened to cover all station apparatus, responsibility is gradually taken away from the operating personnel. Now our industry is no different than any other manufacturing enterprise, in that interest and responsibility are so closely allied that the success or failure of any plan, either operation or maintenance, is in the hands of the operators. The operating crews must be the inspectors, and data taken by them used in reaching an understanding as to the condition of the station equipment.

Major maintenance is scheduled so as to fit in with system load conditions. During the month of November a turbine schedule for the entire system is made up for the following year. The outage allowed each unit is based on past experience and accurate knowledge of work to be done on the turbine, generator and auxiliaries. The outage of the turbine releases a certain number of boilers and their auxiliaries, or the station load may dictate the number of boilers that must be kept available.

Each piece of equipment in the stations is dismantled and overhauled during the year, and it is common knowledge that less system disturbance results where this plan is conscientiously followed through. In addition to the usual work done on a turbine during an overhaul period, every blade is regaged and interstage leakage is checked. The annual overhauling of a turbo-generator with its auxiliaries may cost from 3 to 10 cents per kilowatt capacity, varying with the size of the unit, but this expense is justified by the gain in operating economy and safety. As an example, our No. 4 unit at Gold Street, a 30,000-kw. turbine, was placed in operation during October, 1917. During the past nine years the turbine has been on the bus 59,021 hr. and has generated 949,000,000 kw-hr. A comparison between the guarantee water rate and a test made in August, 1926, shows an increase, during the nine years, of from 1 to 5 per cent. As our usual load on the unit is under 20,000 kw., the actual effect upon operation is 2 per cent or less.

The major portion of our operating personnel have been brought up through the maintenance crew, therefore when equipment is turned over to their attention and care the result is a continuous inspection procedure that is absolutely essential to successful production. Each turbine in operation on the entire system has a fixed load placed upon it at some time during the day, and a periodic check is made at full load with a complete set of readings taken in each case. This same plan is carried out in the boiler rooms, and it can be readily understood that the data so obtained are invaluable to the operating, maintenance, and betterment divisions, in studying station performance, adopting methods to lower the cost of production with existing equipment, and enabling a better understanding of losses that may be decreased by changes in operation, design, or layout.

One other important operating factor still remains, one that has received too little attention both in the press and in the plant, and upon which we lay considerable stress, namely, good housekeeping. Its value, the author believes, is impossible of expression in terms of station performance, but its effect is in evidence nevertheless. The interest exhibited in one's job is largely dependent upon his surroundings. If this is a fact, house cleaning should be a continuous rather than a spasmodic procedure.

Special Cracking to Produce Toluene

IT SHOULD be considered that all sources of toluene in this country are in reality sources producing this material by cracking, which may be used in the general sense meaning the raising of materials to a sufficient temperature to break up the chemical structure to produce different materials. This is true both in the carbonization of coal and in the production of carbureted water gas or of oil gas. None of these cracking systems, however, can be considered of very high efficiency solely for the production of toluene, as these processes are operated primarily for another purpose, although their economic significance in the furnishing of a toluene supply as a by-product incidental to their major operation is not to be minimized.

When, however, the quantity of toluene required or the demand exceeds the economic or possible production from such city-gas sources, then special means must be looked into in order to provide the necessary total supply. This was the condition apparent in the recent emergency, and many systems for the direct special production of toluene from oil by cracking were studied and tried, with many disappointments and failures in the production of the proper characteristics of the finished product. The continuation of these investigations and trials with extensive research and development work finally, however, led to large-scale commercial operation and production of finished toluene of the proper specifications on the Pacific Coast.

The difficulties in the development of processes for this type of cracking are many. The most important difficulty to be overcome is that the finished material must be a pure one and not have oils of other hydrocarbon series, such as paraffins or naphthenes, in it. The unsaturated or olefin series of hydrocarbons of boiling point similar to that of toluene is readily removed from the toluene by the extraction with sulphuric acid. However, as the similar-boiling oils in the paraffin and naphthene series are more stable than the toluene itself when exposed to the action of sulphuric acid, such a means of separation is impossible.

Although it was understood that high-paraffin toluene was being nitrated abroad by separation after a partial nitration, it was apparent that American nitrators would not consider this possibility and demanded a type of toluene which could be handled for full nitration. This required a toluene having a content of less than half of one per cent of such paraffin or other oils.

This difficulty of meeting the proper paraffin content not only existed in producing toluene by direct special cracking, but also was a point continually before the producer of toluol from gas-plant operations. The proper control was given in these operations usually by an increase in temperature or uniformity of gas heat treatments, even though the temperatures necessary might be somewhat higher than that required for most efficient operation both from a gas-production standpoint and a toluene-quantity-production standpoint.

In the special cracking for toluene production this paraffin limitation indicated the necessity of very high temperatures of cracking. The cracking of a petroleum oil, even at comparatively low temperatures as in the production of cracked gasoline, results in the formation of free carbon. The handling of this free carbon naturally accumulating during such cracking has been the principal source of trouble in even the low-temperature cracking for gasoline manufacture. It was found that when the temperatures were raised to such an extent as to produce a toluene sufficiently pure in paraffin oils that the amount of carbon produced was extreme. At the same time it was found that such high temperatures used to break down the paraffin oils decomposed much of the toluene itself, resulting in an increase in benzol, carbon, and gas.

It was found that cracking under pressure resulted in lower total losses, including gas loss, than at low pressures such as those existing in the checker-brick stoves used in the manufacture of carbureted water gas. The final development, therefore, took the form of tubular heaters for heating the oil to cracking temperature, special containers for the accumulating and removal of the separated carbon developed and designed for minimum operating difficulties, and the condensing of the light oil produced, separating it from fixed gas.

This process of cracking, as finally developed and operated, gave a yield of toluene of approximately 5 per cent of the original petroleum oil used when the charging stock consisted of a paraffin-base petroleum as against the yield in carbureted-water-gas manufacture of approximately $2^1/_2$ per cent of the oil so cracked, and in the case of oil gas manufactured of approximately 0.05 per cent of the oil used. (*Army Ordnance*, vol. 7, no. 40, Jan-Feb., 1927, pp. 270–271.)

Methods of Obtaining Economical System Operation

Division-of-Load Report and Its Compilation—Determining Performance—Daily Performance Reports—Accurate Station Instruments a Prime Necessity—Lowest Overall System Economy the Desideratum

By H. M. COOK,[1] BROOKLYN, N. Y.

ONE of the most important features of operating practice is attaining and maintaining economy of operation. Different plants and companies use various methods which are followed more or less systematically with varying degrees of success, but the degree to which different companies participate in work of this kind is most astounding. It varies all the way from absolute disregard to an earnest, conscientious, and systematic attempt to produce the utmost possible with the available equipment.

Some of the large holding companies that operate a number of comparatively small plants scattered over a widely distributed area have not seen their way clear to spend a great deal of money and attention on obtaining high economy. Companies with large concentrations of capacity in single stations of economical design have probably the greatest justification for economy expenditures. In some cases it is the practice to favor these large stations in the matter of load assignment. As near a steady load as possible throughout a maximum of the time is given these stations, resulting in a high load factor. Not only this, but the load is so selected that the station operates at its most economical point for as much of the time as possible. In this way the economical station is able to window-dress its operation and to broadcast an extremely favorable performance. Such a practice, however, may result in a condition which is not conducive to the best economy of a system as a whole. The performance figures of the less economical stations, whose loading and efficiency have suffered as a result of favoring the most economical station, are not mentioned.

It is often more economical, from the viewpoint of system performance, to intentionally load the economical station above its best point during periods of average and peak load, and to leave sufficient load on the poorer stations during low-load periods. This may result in continually running the economical station partly above and partly below its best point, to the detriment of its individual performance, but which may nevertheless produce the best system economy.

It is a practice of the Brooklyn Edison Company to so operate its different stations and to so distribute the load among them that the total kilowatt-hour output of the system is generated at the least possible cost. In attaining this goal it is often necessary to deliberately sacrifice the operation of the most economical station and operate it at a less economical figure than possible. It is sound business, however, to follow the less spectacular method and to produce the system output for the minimum cost, resulting in the largest savings and earnings per share of stock. Production of the average system kilowatt-hour at the minimum cost necessitates, however, considerable preliminary study and work.

The Division-of-Load Report and Its Compilation

As explained in one of the other papers, our system consists of one 25-cycle and two 60-cycle generating stations, which are tied together through a 35,000-kw. synchronous-type frequency changer. For insurance of continuity of operation the rule has been adopted that sufficient excess capacity be carried on the bus at all times, so that in case of sudden failure of the largest unit the remaining machines will carry the load. Under these conditions there is such a wide range of choice in loading not only the individual units but also the stations, that extremely careful and accurate scheduling of apparatus becomes absolutely necessary to obtain maximum economy of operation. For instance, data must be compiled so that economic scheduling of the allotment of load to the different generating stations can be made at all times. Necessary data must also be secured so that schedules to carry the load among the machines in each generating station under any condition can be drawn up.

A division-of-load report containing all the necessary data for daily scheduling the proper division of load among the generating stations and among the machines in each station, is assembled each year for the ensuing year. This report is compiled in the following manner:

The Willans line is plotted for each individual machine in the station. From the Willans lines, input-output curves are made up for each machine, taking boiler efficiencies and auxiliary power consumption into consideration. The input-output curves are plotted with total coal as ordinates and gross load as abscissas. From the input-output curves, first-derivative curves for the different units are obtained by plotting increment increases in coal consumption against unit increases in load. Curves A and B, Fig. 1, show the first-derivative curves of a 50,000- and an 80,000-kw. unit, respectively. Load-division curves for each pair of machines in the station are then plotted from the first-derivative curves. A type of loading curve is shown in Fig. 2. A similar analysis is then made for the other generating stations in the system.

The next step is the compilation of input-output curves of various combinations of units in the station. The input-output curves and loading curves of the individual units are used in computing the combination input-output curves. A sample of these curves is shown in Fig. 3. Coal-rate curves for these same combinations are shown in Fig. 4. Similar curves of input-output and coal rate must then be drawn up for the other generating stations. The same procedure is followed out in the station combination of units as was described for the individual units in the station. Therefore first-derivative curves of the combinations and then loading curves of the combinations are computed. Fig. 5 illustrates a combination loading curve.

With the data thus collected, the input-output curves are compiled for various assumed combinations of units on the system. In making up the combinations the most economical units from the different stations are first selected, and then the units which are next most economical. The maximum operating range of these combinations is determined by the total capacity minus the capacity of the largest unit according to the operating rule previously cited. Input-output curves of the system combinations are shown in Fig. 6, and system combination coal-rate curves in Fig. 7. Loading curves between the two larger stations for two different combinations are shown in Figs. 8 and 9.

The data on which these curves are based are taken from the latest turbine and boiler tests and actual boiler-room and turbine-room performance records. Great care must be exercised to use values that closely approach those obtained in actual operation and to apply the data according to actual conditions at the different stations such as steam pressure and temperature, feedwater temperature, and vacuum.

In using these curves to predict the economy of operation for the coming year it is necessary, however, to estimate the future load demands and outputs. Therefore, semi-logarithmic curves for yearly and monthly system maximum loads and outputs were drawn up. Fig. 10 shows the monthly system maximum loads and Fig. 11 shows yearly system and 60-cycle outputs. Representative load curves for each month were then drawn up to show

[1] Engineer of Tests, Brooklyn Edison Co. Mem. A.S.M.E.

Presented at a meeting of the Metropolitan Section of the A.S.M.E., New York, January 31, 1927.

the expected character of load throughout the year. These curves were obtained by tabulating and averaging the half-hourly loads for the week days of each month of the current year, and multiplying these values by factors obtained from the monthly semi-

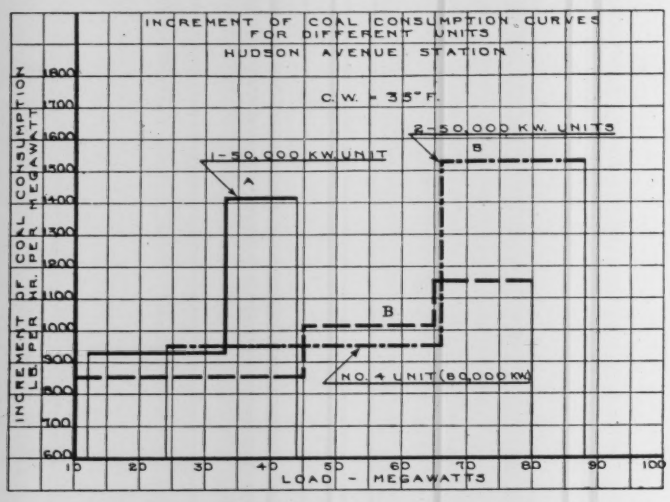

FIG. 1 INCREMENT OF COAL-CONSUMPTION CURVES FOR DIFFERENT UNITS, HUDSON AVENUE STATION

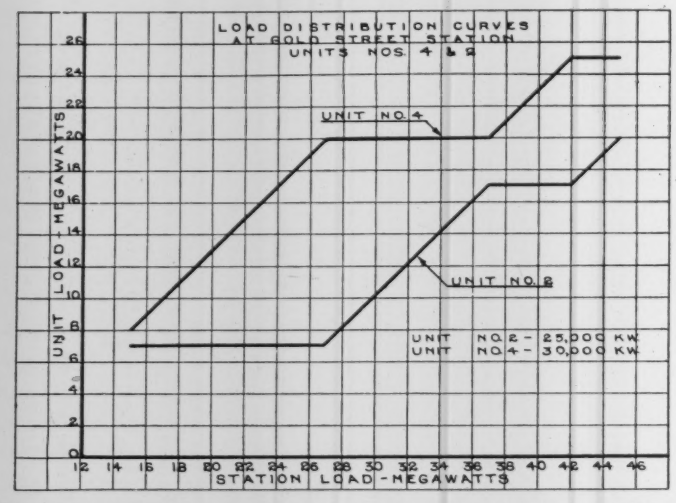
LOAD DISTRIBUTION CURVES
AT GOLD STREET STATION
UNITS NOS. 4 & 2
UNIT NO. 4
UNIT NO. 2
UNIT NO. 2 - 25,000 KW.
UNIT NO. 4 - 30,000 KW.
UNIT LOAD - MEGAWATTS
STATION LOAD - MEGAWATTS

FIG. 2 LOAD-DISTRIBUTION CURVES AT GOLD STREET STATION, UNITS NOS. 4 AND 2

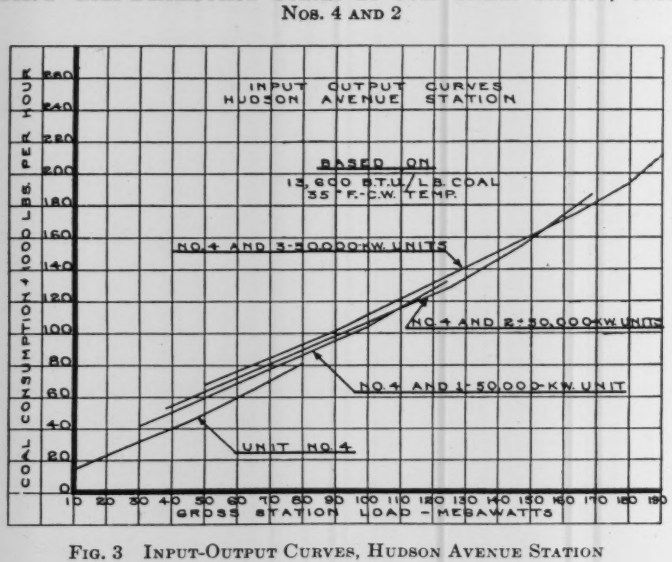
INPUT OUTPUT CURVES
HUDSON AVENUE STATION
BASED ON
13,600 B.T.U./LB. COAL
35° F.-C.W. TEMP.
NO. 4 AND 3-50,000 KW. UNITS
NO. 4 AND 2-50,000 KW. UNITS
NO. 4 AND 1-50,000-KW. UNIT
UNIT NO. 4
COAL CONSUMPTION - 1000 LBS. PER HOUR
GROSS STATION LOAD - MEGAWATTS

FIG. 3 INPUT-OUTPUT CURVES, HUDSON AVENUE STATION

logarithmic increase curves. The average week-day load curve for July, 1927, is shown in Fig. 12.

From the load forecasts and the curves showing proper station load distribution previously referred to, the daily station load

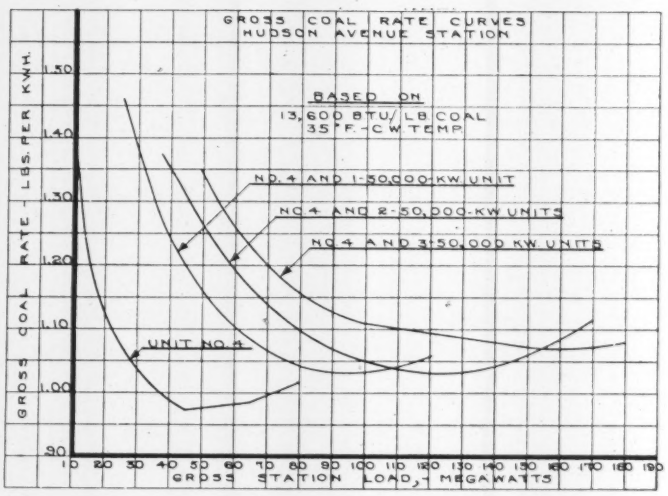
GROSS COAL RATE CURVES
HUDSON AVENUE STATION
BASED ON
13,600 BTU/LB COAL
35° F.-C.W. TEMP.
NO. 4 AND 1-50,000-KW. UNIT
NO. 4 AND 2-50,000-KW. UNITS
NO. 4 AND 3-50,000 KW. UNITS
UNIT NO. 4
GROSS COAL RATE - LBS. PER K.W.H.
GROSS STATION LOAD, - MEGAWATTS

FIG. 4 GROSS COAL-RATE CURVES, HUDSON AVENUE STATION

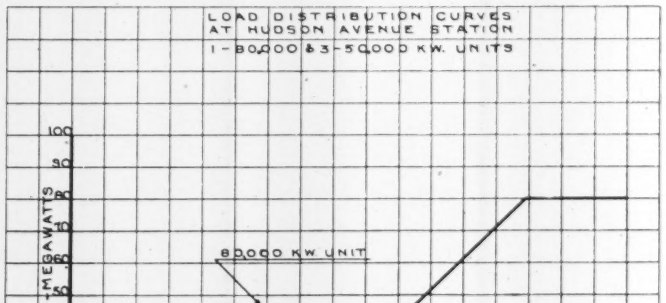

FIG. 5 LOAD-DISTRIBUTION CURVES AT HUDSON AVENUE STATION
(One 80,000- and three 50,000-kw. units.)

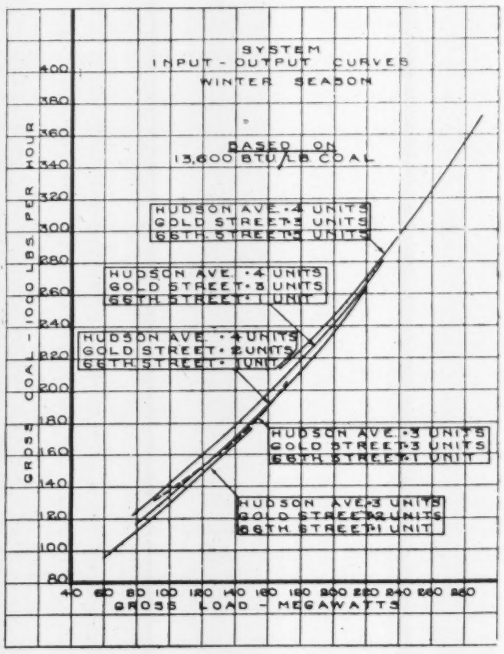
SYSTEM
INPUT - OUTPUT CURVES
WINTER SEASON
BASED ON
13,600 BTU/LB COAL
HUDSON AVE. - 4 UNITS
GOLD STREET - 3 UNITS
66TH STREET - 1 UNIT
HUDSON AVE. - 4 UNITS
GOLD STREET - 3 UNITS
66TH STREET - 1 UNIT
HUDSON AVE. - 4 UNITS
GOLD STREET - 2 UNITS
66TH STREET - 1 UNIT
HUDSON AVE. - 3 UNITS
GOLD STREET - 3 UNITS
66TH STREET - 1 UNIT
HUDSON AVE. - 3 UNITS
GOLD STREET - 2 UNITS
66TH STREET - 1 UNIT
GROSS COAL - 1000 LBS. PER HOUR
GROSS LOAD - MEGAWATTS

FIG. 6 SYSTEM INPUT-OUTPUT CURVES, WINTER SEASON

curves for each month were obtained. Fig. 13 illustrates the station load curves for July, 1927.

With the station load curves and load forecasts, and the load-capacity chart shown in Mr. Cox's paper, the number of boilers for each station for each month can be determined. Knowing the load curve and the number of boilers to be operated, the banked coal can be calculated. For each average week day and for each month, the total coal, coal rate, and kilowatt-hour output for each station and the system can then be figured. Summing up these data for twelve months gives the estimated result of the year's operation, from which the operating costs can also be estimated.

This method of preparing data ahead for a full year's operation gives all the information necessary for daily scheduling the machines and loading for the following day's operation. The curves are utilized in the same way as mentioned in connection with the average week-day load-curve discussion. The report not only provides the necessary information for the most economical operation, but also supplies a target to aim at and a means of carefully checking and grading the actual operation throughout the year.

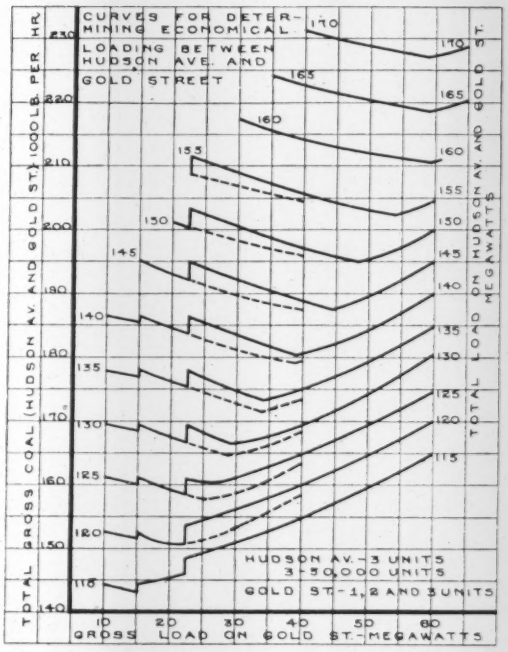
CURVES FOR DETERMINING ECONOMICAL LOADING BETWEEN HUDSON AVE. AND GOLD STREET
HUDSON AV.-3 UNITS
3-50,000 UNITS
GOLD ST.-1, 2 AND 3 UNITS
TOTAL GROSS COAL (HUDSON AV. AND GOLD ST.) 1000 LB. PER HR.
TOTAL LOAD ON HUDSON AV. AND GOLD ST. MEGAWATTS
GROSS LOAD ON GOLD ST.-MEGAWATTS

FIG. 8 CURVES FOR DETERMINING ECONOMICAL LOADING BETWEEN HUDSON AVENUE AND GOLD STREET STATIONS

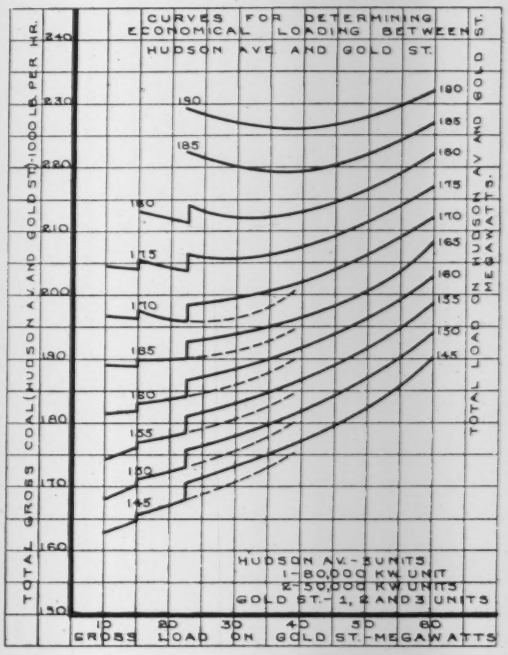
CURVES FOR DETERMINING ECONOMICAL LOADING BETWEEN HUDSON AVE AND GOLD ST.
HUDSON AV.-3 UNITS
1-80,000 KW. UNIT
2-50,000 KW. UNITS
GOLD ST.-1, 2 AND 3 UNITS
TOTAL GROSS COAL (HUDSON AV. AND GOLD ST.) 1000 LB. PER HR.
TOTAL LOAD ON HUDSON AV. AND GOLD ST. MEGAWATTS
GROSS LOAD ON GOLD ST.-MEGAWATTS

FIG. 9 CURVES FOR DETERMINING ECONOMICAL LOADING BETWEEN HUDSON AVENUE AND GOLD STREET STATIONS

Attention must, however, be called to one very important fact. As previously stated, the division-of-load report is based on test and operating data and predicts expected performance based on definite schedules. There is, nevertheless, always the possibility of something occurring to any of the equipment involved to cause its performance to be below what it should be. If any such contingency should actually occur, operation in strict accordance with any predetermined schedule would obviously not produce best efficiency. It is therefore necessary to know not only what performance may be expected of any piece of apparatus, but what its actual performance is *at all times*.

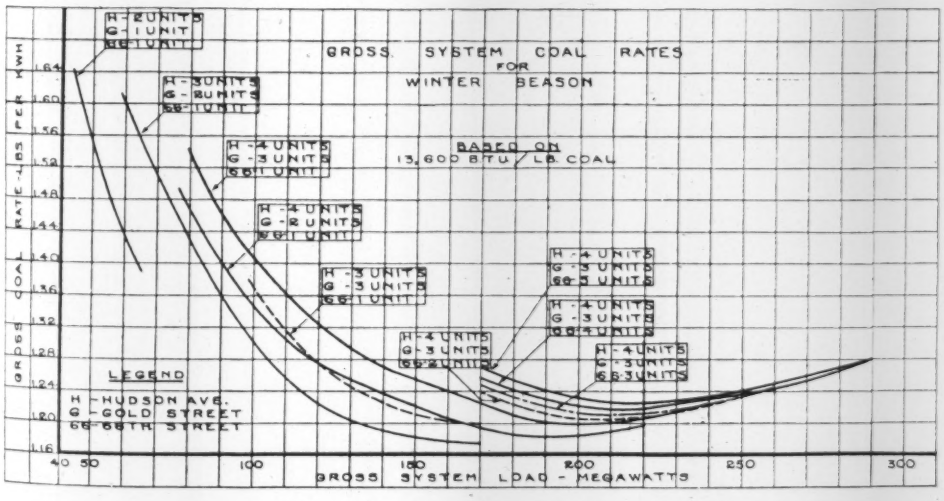
GROSS SYSTEM COAL RATES FOR WINTER SEASON
BASED ON 13,600 BTU / LB. COAL
H-2 UNITS G-1 UNIT 66-1 UNIT
H-3 UNITS G-2 UNITS 66-1 UNIT
H-4 UNITS G-3 UNITS 66-1 UNIT
H-4 UNITS G-2 UNITS 66-1 UNIT
H-3 UNITS G-3 UNITS 66-1 UNIT
H-4 UNITS G-3 UNITS 66-3 UNITS
H-4 UNITS G-3 UNITS 66-4 UNITS
H-4 UNITS G-3 UNITS 66-2 UNITS
H-4 UNITS G-3 UNITS 66-3 UNITS
LEGEND
H-HUDSON AVE.
G-GOLD STREET
66-66TH STREET
KW-HR PER LB. COAL
LOAD ON GROSS
GROSS SYSTEM LOAD - MEGAWATTS

FIG. 7 GROSS SYSTEM COAL RATES FOR WINTER SEASON

DETERMINING PERFORMANCE

To determine the expected or ideal performance of the equipment in question, complete and accurate tests must be made following installation. To determine the actual performance at all times, check tests are made at intervals, and daily, weekly, and monthly operating records are continually inspected, studied, and compared.

As the performance of the station so intimately depends upon the performance of the prime movers, very complete tests throughout the range are made on new turbo-generator units. These tests, in addition to the turbine performance, must include the performance of the condenser, generator air cooler, turbine and condenser auxiliaries, and feedwater heaters. During the spring and summer months, or period of light loads, it is our practice to overhaul all prime-mover units. Before a machine is taken out for overhauling, a water-rate check test is made, and after the machine has been overhauled, another water-rate check is run. The result to be hoped for is that the second water-rate check will coincide with the original water-rate test made on the machine. In addition, an estimate can be made of the savings in operation due to the better economy resulting from the overhauling.

Performance tests are made on new boilers throughout their range in order to establish a perfect operating standard toward which we must always work. After any changes which affect the boiler performance, such as changing baffles or the installation of new baffles or water walls, another series of tests are run with the twofold purpose of reestablishing a standard of operation and of determining the effected improvement.

The same idea is followed throughout our plants and is carried out even down to the auxiliary apparatus—in other words, wherever savings in operation may be obtained by the proper selection and loading of equipment.

With complete data available for the predetermination of economical operation, reports or records of the actual operation become increasingly more valuable. They are the messages which tell of successfully attaining the goal, or else contain the reasons why the goal was not reached. If utilized to their fullest extent, they contain the clues by means of which many troublesome conditions may be uncovered.

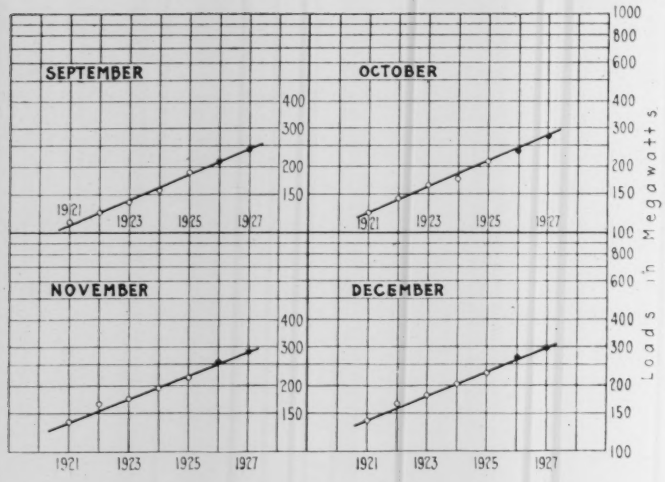

FIG. 10 MONTHLY SYSTEM MAXIMUM LOADS

In general, reports on the performance of equipment can be subdivided into two classes, the division depending upon the use for which the reports are intended. The first class includes reports which are of immediate interest, and are prepared daily. By means of the data taken from this type of report, it is possible to continually tell whether the apparatus is operating satisfactorily or not. Moreover, these reports should contain sufficient information to point out wherein the trouble lies, if the apparatus is not performing up to standard. The second class of reports are those which cover longer periods of time such as a week, month, or year, and are used for comparisons over these longer periods and for official records.

DAILY PERFORMANCE REPORTS

Some of the reports under the first class which we compile cover daily data on main units and condensers, daily boiler performance, daily performance of air preheaters, and classified data on station performance. Figs. 14 and 15 show samples of these reports.

Referring to the daily boiler report, Fig. 15, the performance of each boiler was formerly figured on an input-output basis, but the following objection was soon raised to this method. Whenever a boiler was taken off the line or started up from a cold condition, the efficiency shown would be a ridiculous figure. In the first case advantage would be gained from heat in the coal on the stoker which would not show up against the boiler, and also from heat in the setting. This would often result in an efficiency of over 100 per cent. In the second case just the opposite occurred, and the indicated boiler efficiency would be very low.

The report as now compiled keeps track of the preventable losses, and the boiler efficiency is calculated from the output and the summation of losses. The important controllable losses which this method reflects are losses up the stack and losses due to unconsumed combustible in the ash. This method of obtaining boiler efficiency gives a true reflection of the operation and eliminates the absurdities shown by the former method when starting up or shutting down boilers.

Performance reports covering longer periods of operation such as weekly, monthly, and yearly records, in which such items as efficiency, coal rate, heat consumption, etc., are emphasized, are computed on the input-output basis. This is the more accurate method when the period is long enough to involve large quantities and where slight discrepancies result in negligible percentage errors.

The daily reports are of the greatest value when prepared and completed immediately following the period covered. In order to accomplish this, however, it is necessary to begin the preparation of the data at the moment the twenty-four-hour period ends. Consequently at midnight three junior engineers start on this work, which includes changing of recording charts, reading of recording integrators, planimetering of charts, and the averaging of data. These men must also collect the daily coal samples and quarter them down in preparation for analysis. In this way all

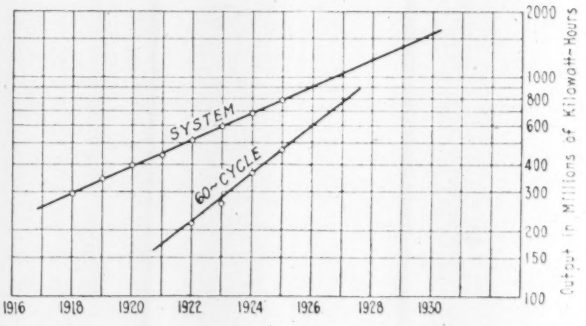

FIG. 11 SYSTEM AND 60-CYCLE TOTAL YEARLY OUTPUT

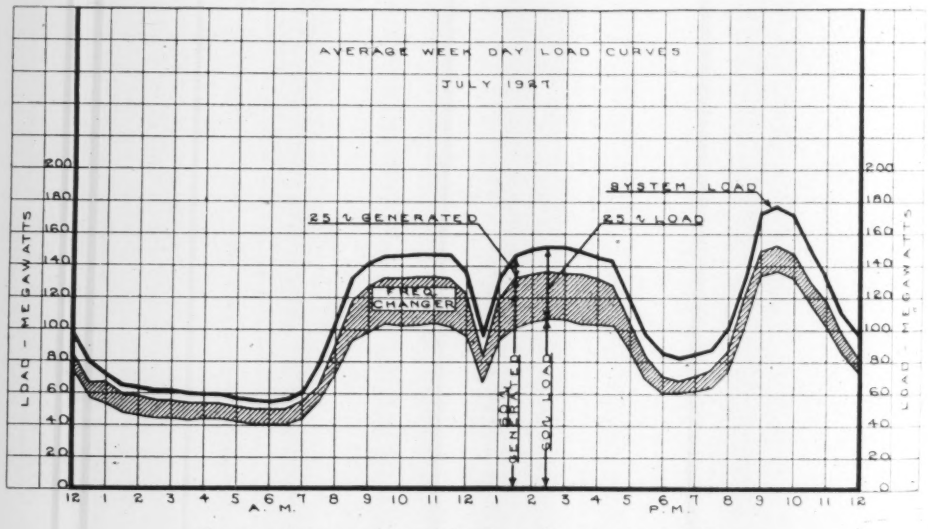

FIG. 12 AVERAGE WEEK-DAY LOAD CURVES, JULY, 1927

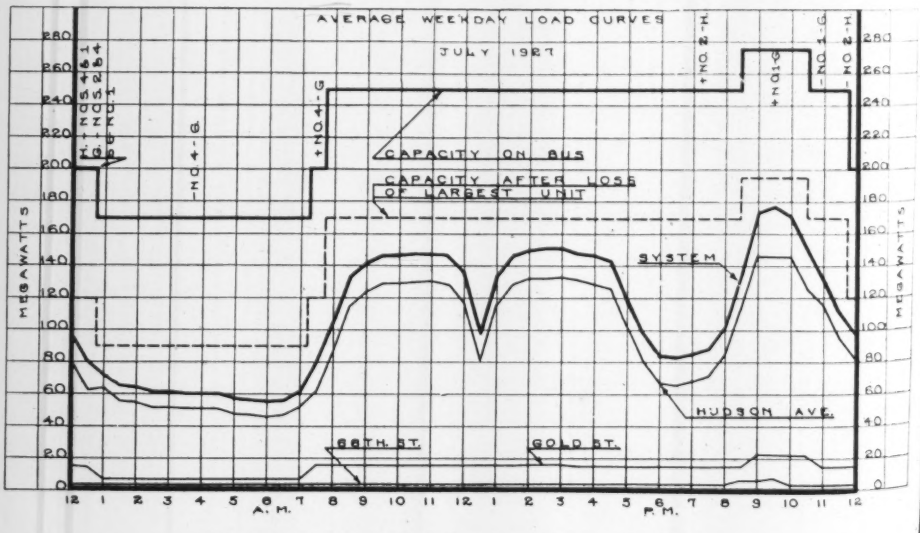

FIG. 13 AVERAGE WEEK-DAY LOAD CURVES, JULY, 1927

DATE FRIDAY DECEMBER 3,1926.	DAILY TURBINE & CONDENSER PERFORMANCE					HUDSON AVE. STATION	
UNIT NO.	1	2	3	4	H.T. 1	H.T. 2	TOTAL OR AVERAGE
PERIOD COVERED HRS.	24	24	24	24			24
K.W.HRS. GROSS	574390	240926	695180	793180			2303676
" " " EXC.	3000	1130	3720	4070			11920
" " " NET	571390	239796	691460	789110			2291756
TURBINE HRS.	18.00	6.97	24.00	24.00			72.97
AVERAGE LOAD, K.W.NET	31700	34300	28800	32900			31400
TURBINE CONDENSATE LBS.	5760000	2496000	7392000	7440000			23088000
BLEED STEAM COND. "	1260000	540000	1404000	2064000			5268000
EVACTOR " " "	28800	11150	38400	38400			116750
GLAND WATER " "	46800	18150	62400	62400			189750
MAKE UP " "		152000	520000				672000
TOTAL CORREC." "	6944400	2854700	8175200	9403200			27377500
W.R. ACTUAL LBS./KW.HR.	12.15	11.91	11.83	11.91			11.95
W.R. CORREC. DUE TO PRESS.	+.012	+.017	+.007	-.074			-.019
" " " " " SUPERHEAT	-.170	-.143	-.355	-.212			-.237
" " " " " VACUUM	+.110	-.044	.000	+.167			+.081
W.R. CORREC.LBS./KW.HR.	12.102	11.740	11.482	11.791			11.775
BAR.CORREC.	30.30	30.30	30.30	30.30			30.30
STEAM PRESS. AT THR. #/SQ.IN.	270	272	268	359			270 359
" " " PRIMARY #/SQ.IN.	229	237	220	238			229 - 238
" TEMP. AT THR. °F.	596	598	575	655			590 - 655
SUPERHEAT °F.	183	185	163	216			177 - 216
VAC.REF.TO 30 IN.BAR.	29.14	28.93	29.00	29.14			29.05
TEMP. OF COND. °F.	72	75	76	75			75
THERMAL EFF. %	26.2	27.1	26.7	26.3			26.6
CIRC. WATER TEMP. IN. °F.	45	45	45	45			45
" " " OUT.	54	54	54	63			56
" " LBS. (THOUSANDS)	568400	231500	677100	366900			1843900
B.T.U. LOSS TO RIVER (10^4)	511560	208350	609390	660420			1989720
% " " "	56.1	55.6	57.3	52.5			55.1
MEAN TEMP. DIF.(LOG) °F.	24.7	31.6	29.3	19.1			26.7
B.T.U. TRANS./SQ.FT./1° MTD	164	135	124	180			139

FIG. 14 DAILY REPORT ON TURBINE AND CONDENSER PERFORMANCE

the data are prepared between midnight and 9:00 a.m. for the day force. The final calculations are completed by the day force, and all these reports are finished and ready before noon of the day following that for which the report is made. In order to expedite this work as much as possible and to prevent errors, curves and charts are used to a great extent in the making of calculations. Samples of the labor-saving charts used are shown in Figs. 16 and 17. By using these charts and curves it is possible for clerks to handle the computation work. With our arrangement, one engineer supervises the performance-report work of several clerks.

Assembly of the records is absolutely worthless, however, unless supplemented by intelligent thought, study, and use of the information contained. Quite often helpful and beneficial facts will be hidden away and will require digging before they are uncovered. They are not always apparent or on the surface. Discussion of the performance records of the previous day at daily meetings is one of four ways in which the operating force obtains information regarding the functioning of the station and apparatus. The other three ways are through contact with the test men in the station, dissemination of station-performance data at instruction

DAILY BOILER PERFORMANCE
LOW-PRESSURE STATION

DATE Friday December 3, 1926. TEST BUREAU
HUDSON AVE. STATION

BOILER NO.		11	12	13	14	21	22	23	24	31	32	33	34	TOTAL
HOURS STEAMING		24	22	22	24	24	24	0	24	24	24	20	22	254
HOURS BANKED		0	2	2	0	0	0	0	0	0	0	4	2	10
HOURS OUT		0	0	0	0	0	0	24	0	0	0	0	0	24
B.T.U. IN COAL (FIRED)		13470	13470	13470	13470	13510	13510		13510	13510	13510	13510	13610	13495
B.T.U. IN COAL (DRY)		14070	14070	14070	14070	14150	14150		14150	14150	14150	14150	14150	14120
STEAM PRESSURE	#/Sq.In.G.	277	277	277	277	277	277		277	281	281	281	281	278
STEAM TEMPERATURE	°F	590	592	596	602	597	600		601	587	585	594	586	594
FEED WATER TEMP.	°F	272	272	272	272	272	272		272	272	272	272	272	272
BOILER RATING (24 HRS)	%	112	105	112	116	115	122		133	107	104	103	97	111
BOILER RATING (ST'M. HRS.)	%	112	115	122	116	115	122		133	107	104	124	106	116
EXCESS AIR	%	44.0	46.8	31.5	52.4	53.4	33.0		33.0	47.5	34.2	44.5	57.0	43.4
FLUE GAS TEMP.	°F	479	473	484	508	498	494		476	481	481	486	459	483
FLUE GAS TEMP. ABOVE GUAR.	°F	27	20	29	55	45	39		18	30	31	31	9	30
STACK LOSS	%	12.65	12.70	11.80	14.15	13.90	12.15		11.70	13.05	11.90	12.85	13.00	12.71
ASH LOSS	%	1.26	1.26	1.26	1.26	1.26	1.26		1.26	1.26	1.26	1.26	1.26	1.26
MOISTURE LOSS	%	.40	.40	.40	.40	.42	.42		.42	.42	.42	.42	.41	.41
HYDROGEN LOSS	%	3.55	3.54	3.56	3.58	3.58	3.57		3.55	3.56	3.56	3.56	3.53	3.56
BANK LOSS	%	.00	.55	.56	.00	.00	.00		.00	.00	.00	1.08	.58	.25
RADIATION LOSS	%	1.19	1.17	1.14	1.17	1.17	1.14		1.09	1.21	1.23	1.13	1.22	1.17
UNACCOUNTED LOSS	%	2.23	2.29	2.43	2.31	2.29	2.43		2.65	2.13	2.07	2.47	2.11	2.31
BOILER EFF. (100% - % LOSSES)	%	78.70	78.09	78.85	77.13	77.38	79.03		79.33	78.37	79.56	77.23	77.89	78.33
COMP. BOILER EFF. (50°F.Air)	%	79.45	78.79	79.65	77.88	78.08	79.78		80.08	79.12	80.26	77.98	78.64	79.06

		L.P. STATION
GROSS STATION OUTPUT	K.W.	1510475
AUXILIARY POWER	K.W.	68981
NET STATION OUTPUT	K.W.	1441494
TOTAL FEED WATER	LBS.	18853000
STATION WATER RATE	LB./KWH	13.09 - 12.56

		L.P. STATION
TOTAL COAL (AS FIRED)	LBS.	1913000
NET COAL RATE	LB./KWH	1.327
B. T. U. PER NET K.W.H.(STATION)		17900
STATION THERMAL EFF. -	%	19.06

FIG. 15 DAILY REPORT ON BOILER PERFORMANCE

classes of the Company school, and the daily posting of charts and cards containing vital performance data. Each of these four ways of acquainting the operating personnel with data regarding the performance of the equipment will be discussed more elaborately in the paper by Mr. Holmes. They are mentioned here, however, as they are considered important points in the ultimate attainment of economy.

ACCURATE STATION INSTRUMENTS A PRIME NECESSITY

In connection with continually obtaining maximum efficiency of a station corresponding to its assigned load, one very important item must not, however, be overlooked. Since operation of the stations is guided by the respective reports, if the reports are incorrect, due to erroneous or inaccurate fundamental data on which they are based, the operation will obviously not be up to standard. It follows, therefore, that the various station instruments, from which the necessary data for the reports are taken, must be known to be accurate at all times. To insure this exacting but necessary qualification, careful selection of the type of instrument installed is but one prerequisite. Very close and careful maintenance is of utmost importance.

As the number of instruments in modern stations soon becomes a formidable quantity, they must be reliable so that their maintenance will be as small as possible. Cheap, unreliable instruments have no place in a power plant. After the instruments are installed, they must be utilized to the fullest extent to justify their presence.

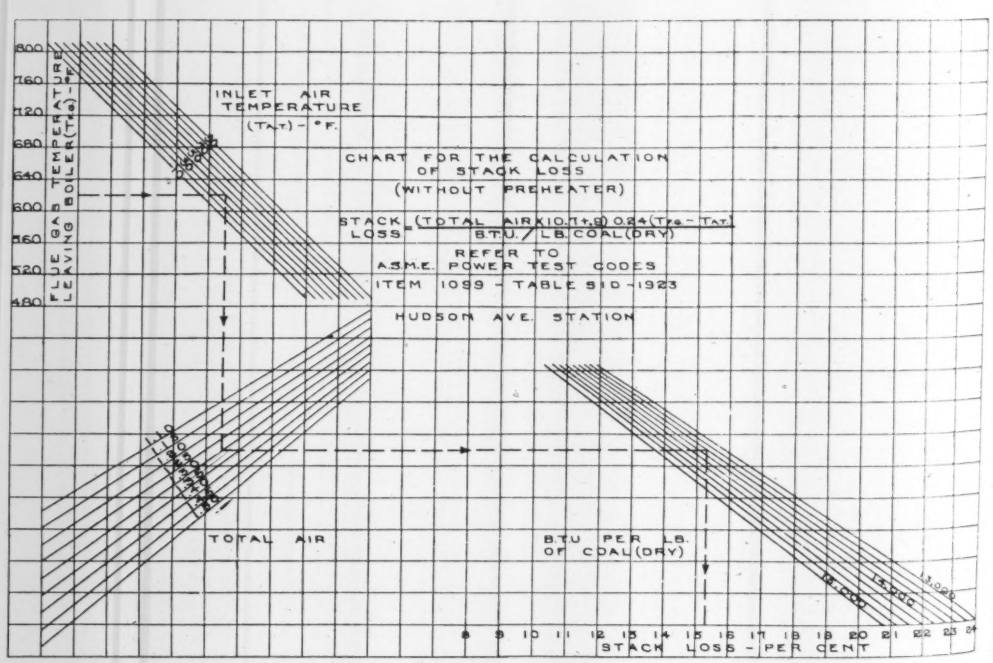
FLUE GAS TEMPERATURE LEAVING BOILER (Tg) - °F.
INLET AIR TEMPERATURE (TA.T) - °F.
CHART FOR THE CALCULATION OF STACK LOSS
(WITHOUT PREHEATER)
STACK LOSS = (TOTAL AIR)(1+B).024(Tg - TA.T.) / B.T.U. / LB. COAL(DRY)
REFER TO A.S.M.E. POWER TEST CODES ITEM 1099 - TABLE 9 ID - 1923
HUDSON AVE. STATION
TOTAL AIR
B.T.U. PER LB. OF COAL(DRY)
STACK LOSS - PER CENT

FIG. 16 CHART FOR THE CALCULATION OF STACK LOSS (WITHOUT PREHEATER)

DAILY BOILER PERFORMANCE — TEST BUREAU

DATE FRIDAY DECEMBER 3, 1926 — HIGH PRESSURE STATION - TOTAL STATION — HUDSON AVENUE STATION

BOILER NO.	41	42	43	44	51	52	53	54	TOTAL 41 - 54	TOTAL 11 - 34	TOTAL FOR STATION
HOURS STEAMING	18	24	24						66	254	320
HOURS BANKED	6	0	0						6	10	16
HOURS OUT	0	0	0						0	24	24
B.T.U. IN COAL (FIRED)	13490	13490	13490						13490	13495	
B.T.U. IN COAL (DRY)	14110	14110	14110						14110	14120	
STEAM PRESSURE LB./SQ.IN.G.	390	390	390						390	278	
STEAM TEMPERATURE °F.	642	632	637						637	524	
FEED WATER TEMPERATURE °F.	320	320	320						320	272	
BOILER RATING (24 HRS.) %	158.5	209	179						182	111	
BOILER RATING (ST'M. HRS.) %	198	209	179						195	116	
EXCESS AIR %	21.9	32.5	22.0						25.5	43.4	
FLUE GAS TEMP. OUT OF BOILER °F.	586	567	554						569	483	
F.G. TEMP. OUT OF BOILER-ABOVE GUAR. °F.										30	
FLUE GAS TEMP. OUT OF PREHEATER °F.	223	269	261						251		
F.G. TEMP. OUT OF PREHEATER-ABOVE GUAR. °F.											
AIR TEMP. OUT OF PREHEATER °F.	372	342	357						357		
STACK LOSS %	13.32	13.89	12.60						13.27	12.71	
ASH LOSS %	1.26	1.26	1.26						1.26	1.26	
MOISTURE LOSS %	.42	.41	.41						.41	.41	
HYDROGEN LOSS %	3.65	3.63	3.62						3.63	3.56	
BANK LOSS %	1.77	0	0						.59	.25	
RADIATION LOSS %	2.71	2.67	2.79						2.73	1.17	
UNACCOUNTED LOSS %										2.31	
BOILER EFF.(100% - % LOSSES) %	76.87	78.14	79.32						78.11	78.33	
INCREASE IN EFF. DUE TO PREHEATER %	7.06	7.62	7.10						7.26		
TOTAL EFF. INCLUDING PREHEATER %	83.93	85.76	86.42						85.37		
COMP. BOILER EFF. (50° AIR) %	84.02	85.87	86.52						85.47	79.06	
STACK LOSS WITH PREHEATER %	6.67	6.61	5.84								
HYDROGEN LOSS WITH PREHEATER %	3.24	3.29	3.28								

	H.P. STATION	TOTAL STATION
GROSS STATION OUTPUT K.W.	793200	2303675
AUXILIARY POWER K.W.	39025	108006
NET STATION OUTPUT K.W.	754175	2195669
TOTAL FEED WATER LB.	10009920	28863000
TOTAL COAL(AS FIRED) LB.	839140	2752140
AIR INLET TEMP. TO PREHEATERS °F.	110	
HOT AIR TEMP. TO STOKERS. °F.	298	

	H. P. STATION	TOTAL STATION
* STATION WATER RATE LB./K.W. HR.	13.25 - 12.61	13.15 - 12.52
NET COAL RATE LB./K.W. HR.	1.112	1.254
B.T.U. PER NET KW.HR. (STATION)	15000	16910
STATION THERMAL EFF.	22.76	20.19
* WATER RATES ARE GIVEN NET AND GROSS		

(FIG. 15 *Continued*)

The attitude of the station operators toward the instruments installed is a rather significant sign as to the extent of their usefulness. In our own stations, stoker attendants who formerly knew or cared nothing about instruments now insist they must have boiler meters and draft gages to operate the boilers. They hesitate to run a boiler until these aids are connected up and are in good operating condition. Two things have contributed to this development: first, a tactful demonstration of the differences in furnace conditions which can be obtained by their use, and second, a grading of their operation and commendation when results warrant it.

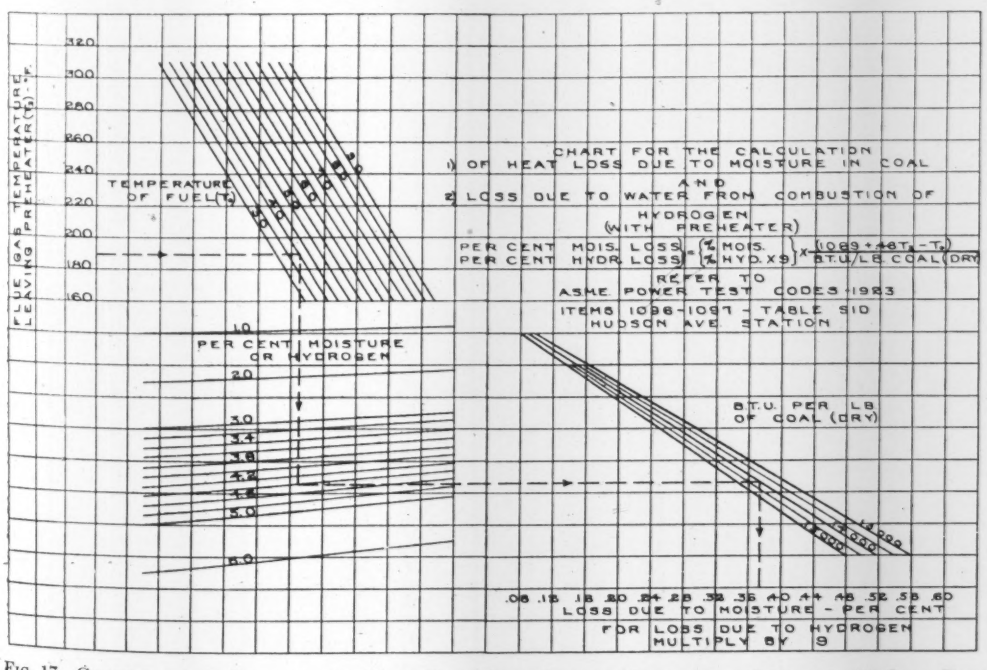

FIG. 17 CHART FOR THE CALCULATION (1) OF HEAT LOSS DUE TO MOISTURE IN COAL, AND (2) LOSS DUE TO WATER FROM COMBUSTION OF HYDROGEN (WITH PREHEATER)

With such a large number of instruments installed, and because of the desirability of changing charts and reading integrators at midnight, a night crew becomes essential. At the Hudson Avenue Station the three junior engineers who start the daily report work during the night shift include care of the instruments along with their duties of changing recording charts, reading integrators, etc. This crew inspect all instruments, clean and ink pens, and take care of any minor repairs that they find.

Every week day each meter and instrument in the plant is inspected.

This inspection is made in the daytime in addition to the one made during the night shift. The night examination does not suffice as the instrument readings are low or near zero due to the low load on the plant. During the daytime, when the instrument readings are normal, it is easy to tell whether the meter is in good operating condition or not.

All boiler meters are checked on the steam-flow–air-flow zero every morning. The calibration of these instruments is very important as good boiler performance is dependent upon maintaining the correct steam-flow–air-flow relation. Several factors may upset the calibration of these instruments. The ones which usually affect the air-flow portion are soot and slag on heating surfaces, leaks in pipe lines, plugged pipe lines, low oil level in the meter, and bent pen arms.

Most of these defects are easily discovered in the daily inspection. If they are overlooked or any obvious defect develops between inspections, the stoker attendant quickly notices and reports it. If for some reason action is not promptly taken, he immediately makes it known to all persons responsible. This fact is another reflection of the interest and earnest attitude of this class of labor toward the attainment of economy.

On account of the change in calibration due to the accumulation of soot and slag on heating surfaces, a weekly check is made on the steam-flow–air-flow relation at the higher ratings. This check is made in the following manner. First, the steam pen is checked on zero. The air-flow lines are disconnected and the air-flow balance checked. With ideal furnace and ashpit conditions, five flue-gas samples, each taken over a ten-minute period, are analyzed by an Orsat. The radius is reset if necessary and, with pens together, another Orsat check is made. Beside the regular weekly check, a similar check is made when any clean boiler is started as soon as furnace conditions permit.

The calibration of the steam-flow part of the boiler meters is particularly important because of its use in the calculation of the boiler performance. The commonest troubles which affect its calibration are bent pen arms, leaks in meter or piping, dirt in meter, and loss of mercury. A casual inspection may not reveal these defects, and therefore, in order to detect promptly any change in calibration, several methods of daily checks are used.

The steam-flow part of the meters on the individual boilers is checked by the evaporation of each boiler. This figure is computed daily, using the lorry coal weight for each boiler, and the figure is compared to the normal value. When an evaporation shows above or below normal, the meter is carefully inspected, checked on zero, and lines blown down. If no change is shown on the following day, the meter is opened up and cleaned, the mercury filtered, the levels checked, and the meter put back into service. These meters are also checked daily as a group by the following methods. The total steam metered on all boilers is used to compute the station steam rate. Values from the venturi meters on the main-unit condensate, heater condensate, and estimated auxiliary exhaust are totaled and compared with the steam rate previously figured. These two values usually check within one per cent. The total feedwater measured on venturis minus blowdown is also compared with the steam rate from the boiler meters. This value does not check with the steam rate as closely as the condensate, its maximum difference being of the order of two per cent plus or minus. Difficulty in metering the blowdown explains this deviation. By these methods of comparing steam rates, any material change in calibration is easily detected.

Lowest Overall System Economy to Be Striven for, Not Merely That of a Single Station

In conclusion, the fact cannot be overemphasized that lowest overall system economy should be striven for, and not merely the performance of a single station. To obtain the best results with the equipment at hand, knowledge of performance throughout its entire range is essential. Testing supplies this information, and it must be continuous so that the latest conditions will always be available. The arrangement of the known data of the equipment for a considerable period ahead provides means of properly scheduling the turbines, boilers, and auxiliaries to obtain the best results under the different load conditions. The arrangement of test and operating data in the proper form will provide the goal to strive toward in the operation of the system, stations, machines, boilers, and auxiliaries. Prompt reports of the results of daily operation of system, station, and the more important equipment give the necessary check and reveal whether the plans are being properly carried out. They detect the faults with operation and the equipment, and furnish the clues for correcting them. The means for carrying out the prepared schedules are furnished with the indicating instruments, and the veracity of the reports depends upon the recording instruments. Reliable and tried instruments are therefore the only ones worthy of consideration, and systematized care, maintenance, and checks keep them tuned up for their important function.

Expenditures for complete instrument equipment and for labor in planning economical operation and compiling detailed operating reports are often questioned as a doubtful investment. The cost of such work amounts to only a fraction of one per cent of the thermal efficiency of a large modern station, although the possible savings may easily reach several per cent in thermal efficiency.

Improvements in Oil Absorption Recovery Systems

THE Pacific Coast has contributed largely to improvements in oil absorption recovery systems during the last few years. This has been due not to the recovering of light oils from city manufactured gas or from coke ovens, but due to the enormous increase in the development of recovery of gasoline from natural gas using the same process.

When it is realized that the natural-gas gasoline manufactured in the United States during the year 1918 amounted to only 282,000,000 gal. and that only 63,000,000 gal. of this was at that time manufactured by absorption systems, and that this has increased to 1,105,000,000 gal. in 1925, principally by the oil absorption system, it can readily be seen on what an extensive scale development and construction have been going on during the intervening period.

There are quite a few plant and equipment manufacturers on the Pacific Coast who have spent large sums in research work on the absorption system, and this has resulted in greatly improving the efficiency of absorption for removal of light oil or gasoline from the gas; in increasing the efficiency of removal of the light oil from the absorption oil; in reducing the size and expense of heat exchange and other parts of the equipment, and in reducing steam or fuel consumed in the process as well as operating expense through the installation of automatic regulation, etc.

Such equipment has been standardized throughout and the definite rating of each piece of apparatus is known for service under usual conditions. The installation of this equipment at any point, therefore, is made more simple, and each installation being a new and separate design job, is past history.

For a time improvements in absorption towers consisted of the installation of different kinds of filling material of large surface in order to give more intimate contact between the gas and oil, together with means for distributing and redistributing the oil over this surface. At the same time, mechanically operated absorbers were tried out in different fields. There will be differences of opinion in different field points as to the results being obtained, but it may generally be stated that the more efficient installations are now developing toward the installation of various types of bubble towers as absorbers. The gasoline recovery industry did not generally use bubble-type stripping stills until recently. These are now pretty generally adopted, are of improved design and, with the higher temperatures of preheat which have been adopted in the last few years, are stripping their oil extremely clean. Bubble fractioning towers are also being employed to make clean separation between the absorber oil and the light oil produced. (*Army Ordnance*, vol. 7, no. 40, Jan-Feb., 1927, pp. 269–270.)

The Operation of the Hudson Avenue Generating Station of the Brooklyn Edison Company

Data on Section of Station Employing 300 Lb. Boiler Pressure—Layout of No. 4 Unit, an 80,000-Kw. Cross-Compound Machine—Operation of 300-Lb. Section Units—Auxiliary Drives —Operating Results on 300-Lb. Section

By W. C. HOLMES,[1] BROOKLYN, N. Y.

THE Hudson Avenue Generating Station of the Brooklyn Edison Company has been in continuous operation since July, 1924. The initial capacity of the plant was 100,000 kw. in two units of 50,000 kw. each. In November, 1924, an additional 50,000-kw. unit was added. These three units operate on 300 lb. boiler pressure, and the apparatus layouts of all three are practically identical. Number 4 unit, of 80,000 kw. capacity and operated on 400 lb. boiler pressure, was put in commission in October, 1926.

The 300-lb. section of the station has been fully described in the technical press, so a brief outline will suffice here. The 400-lb. section has not as yet been so described, and accordingly is more completely discussed.

300-Lb. Section Comprising Units 1, 2, and 3

Each 50,000-kw. turbine is served by a 70,000-sq. ft. radial-flow surface condenser. Two circulating pumps are provided, each driven by a two-speed pole-changing induction motor. Both pumps are normally operated at the lower speed except at such times in the summer months when the additional vacuum obtainable with the pumps in high speed justifies the additional power cost. The air-removal apparatus consists of a two-stage steam-jet air pump and hydraulic vacuum pump. The former is normally used as the absence of moving parts makes it very reliable and keeps the maintenance costs down below those of the rotary pump. The hotwell pumps are also in duplicate.

The turbines are bled at two points into closed feedwater heaters, both of which are on the boiler side of the feed pumps. No regulation of the bleed steam is necessary, as the heaters extract enough steam from the turbines to heat the feedwater within a few degrees of the saturation temperature of the steam in the extraction stages of the turbines. The condensate in the high-pressure heater is cascaded into the low-pressure heater through a continuous-discharge trap. Part of it flashes into steam and is recondensed with the low-pressure bleed steam. The combined heater condensate is then pumped to the feed-pump-suction header. In order to protect the turbines against reversal of flow in the bleed lines, in the event of leaks in the heater tubes too large to permit the heater-condensate pumps to remove the water, special non-return valves were developed. These are float-actuated to close when the level of the water in the heater reaches a predetermined height. To remove the water if this occurs, relief valves are provided which discharge to an open trench.

An 11,000-gal. surge tank is connected to the feed-pump-suction header. The level of water in this tank controls the make-up to the system through a float valve. The make-up is thus regulated automatically to meet the demand. It is taken into the condenser from the storage water tank, so no pumps are required.

There are five boiler-feed pumps, three of which are driven by wound-rotor induction motors and two by steam turbines. The boilers are normally fed by the motor-driven pumps, but one steam pump is always kept turning over slowly, ready to pick up the load if a motor-driven pump drops out. The feedwater pressure is manually controlled by the feed-pump attendant, who has gages and a load indicator for his guidance.

In order to insure sufficient feedwater at all times, two feed lines supply each boiler drum. Each line is large enough to carry the water requisite for maximum rating. At the boiler the feed is controlled by thermostat-type regulators. A pressure of 50 to 75 lb. is carried across the regulator valves to further insure adequate supply of water at all times. Troubles have been reported in other stations when the pressure drop across the regulator valves is carried this high, but at Hudson Avenue as yet there has been no difficulty with feedwater control. It is possible that this may be accounted for by the very close regulation of steam pressure which is maintained in this station.

There are twelve 1965-hp. boilers in this part of the station, each served by a 14-retort underfeed stoker. Six stokers are of one manufacture, with double-roll clinker grinders, and six are of another make, with single-roll grinders. Coal is delivered to the stoker hoppers from the overhead bunkers by means of weigh lorries. The ash is ground through the clinker rolls, falls into a cast-iron trough, and is sluiced out to a pit on the dock. The ash is removed from the pit by an electric locomotive crane and deposited on a scow. Formerly it was necessary to pay a contractor to remove the ash, but in recent years there has been so much building construction going on that competition has become keen, and the contractor is willing to pay for all the ash turned out.

The boilers are set in rows of four with a common flue and stack for two rows. As there are no air preheaters or economizers in this part of the station, maintaining good boiler efficiencies is of the utmost importance.

Layout of No. 4 Unit

The layout of No. 4 unit and the four boilers which serve it follows in general the design of the older part of the station. No. 4, however, is an 80,000-kw. unit, while the older machines are of 50,000 kw. capacity. As there was no more room available for the boilers serving No. 4 than there is for the older boilers, it became necessary to operate at higher boiler ratings. It also became highly desirable for reasons of space limitation as well as general economics to design for high overall efficiency.

After careful studies it was decided to operate this unit on 400 lb. steam pressure and 700 deg. total temperature. It was also decided to install air preheaters and to bleed the unit at four points for feedwater heating. On account of the high boiler ratings necessary, nearly 400 per cent, water screens on the side and rear boiler walls and carborundum brick on the front wall were deemed advisable.

The turbine is an 80,000-kw. cross-compound machine. The high-pressure element is single-flow and operates at 1800 r.p.m. The low-pressure element is double-flow and also operates at 1800 r.p.m. Each element drives a 40,000-kw. generator having a 90 per cent power factor. In addition, the high-pressure element drives an exciter for the two generators.

The steam chest containing three control valves is mounted several feet in front of the high-pressure turbine and is anchored to the building steel. Four long flexible pipe bends connect the steam chest to the high-pressure turbine. This construction very greatly simplifies the problem of providing sufficient flexibility in the steam line. Any one who has had this problem to solve will realize how difficult it would be to lay out a 22-in. pipe, 1 in. thick, which would not throw strains on the steam connection of the turbine.

The cross-over pipe between the high-pressure and low-pressure turbines contains a rather elaborate water-sealed expansion joint. The water for this joint and for the glands is taken from the discharge side of the hotwell pumps and pumped up to a gravity-feed tank in the boiler house. This simplifies the daily calculations of water rate and eliminates the necessity of weighing this water when testing the unit.

[1] Superintendent, Hudson Avenue Station. Assoc-Mem. A.S.M.E.

Presented at a meeting of the Metropolitan Section of the A.S.M.E., New York, January 31, 1927.

The turbine is served by an 80,000-sq. ft., radial-flow two-pass condenser. The water boxes are divided vertically to permit operation of one side while the other side is being cleaned. There are two circulating pumps of 50,000 gal. per min. capacity, each driven by a two-speed squirrel-cage induction motor. Two hotwell pumps, each of sufficient capacity for full-load operation and each driven by a two-speed induction motor, are provided. The air-removal apparatus consists of one hydraulic pump and one three-stage steam-jet air pump. The latter is normally used on account of its greater reliability and low maintenance.

As the turbine has a single exhaust opening, it is bolted directly to the condenser which is supported on springs.

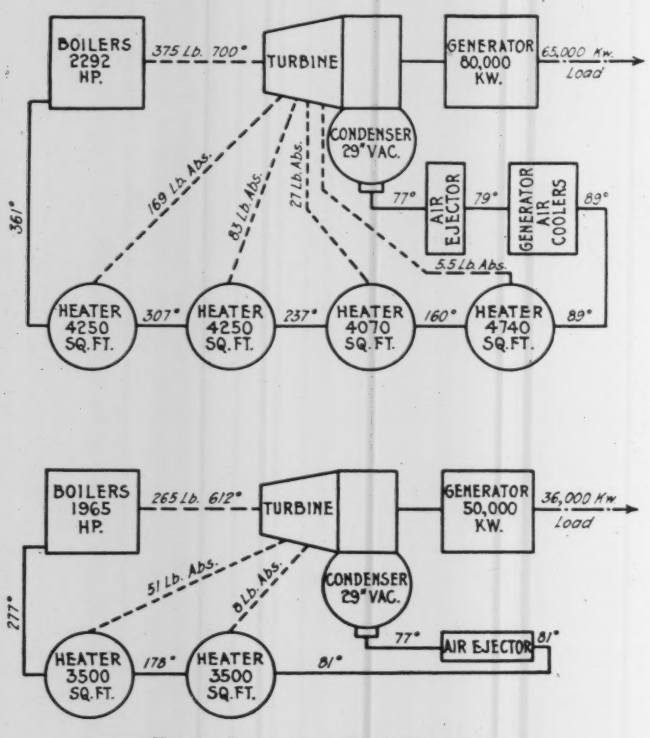

FIG. 1 DIAGRAM OF HEAT BALANCE

Each generator is equipped with an air cooler in two sections. One section uses condensate from the main unit as the cooling medium. The second, which is cut in when the condensate section is insufficient due to light loads or warm circulating water, and hence warm condensate, uses either well water or salt water. The condensate section is placed in the heat balance between the aftercooler of the steam-jet air pump and the low-pressure heater.

The turbine is bled from four points to closed feedwater heaters. At 65,000 kw., the most economical load, the feedwater temperature is approximately 360 deg. fahr. The condensate is forced through No. 4 heater by the hotwell pumps. The three remaining heaters are on the high-pressure side of the boiler-feed pumps. All heaters are of the straight-tube, flowing-head type with Admiralty tubes and Muntz tube sheets. The condensate from each of the first three heaters is cascaded to the heater of next lower pressure; that from the last one is pumped to the feed-pump-suction header. The air vents are similarly cascaded down to the low-pressure heater and thence to the condenser.

The boiler feeders are 1000-gal.-per-min. six-stage single-suction pumps with bronze casings and runners. They are designed for 525 lb. discharge pressure and are set 25 ft. below the surge tank which floats on the suction header. Three pumps are driven by wound-rotor induction motors, the fourth by a single-stage steam turbine. The latter is fed by the auxiliary steam header supplied from the 300-lb. boilers. It exhausts into the low-pressure heater or, this being out of commission, to atmosphere.

Fig. 1 shows a diagram of the heat balance of No. 4 unit and one of the low-pressure units. Due to the two operating pressures, the system of No. 4 unit is kept entirely separate from the remainder of the station. Thus there are now virtually two independent stations under the same roof, being tied together only in the switch house on the electrical end. Ties in the feed-pump-suction headers are provided, however, which may be used in an emergency.

In order to permit using the 400-lb. boilers when No. 4 unit is not running, due to load conditions, annual overhaul, etc., and to prevent the large losses due to starting up and taking off these boilers, a tie line between the 400-lb. and the 300-lb. steam headers is now under construction. This tie line includes a desuperheater as well as pressure-reducing valves, because all of the turbines in the 300-lb. section of the station are not suitable for operation on 700-deg. steam. The desuperheater is similar in design to a U-tube closed feedwater heater. It consists of a steam chest divided by a partition, the inlet and outlet sides being connected by U-shaped tubes. The tubes are enclosed in a steel drum.

The cooling medium is water from the 300-lb. boiler-feed lines. It is introduced into an auxiliary drum set at the same elevation as the drums of the 300-lb. boilers. The water level in this drum is controlled by the same type of feedwater regulators as are used on the boilers. Water from this drum flows by gravity into the drum of the desuperheater. Here it is evaporated in cooling the steam from the 400-lb. boilers from 700 deg. to 615 deg. The steam thus formed is piped to the top of the auxiliary drum and from there to one of the 300-lb.-boiler drums. Control of the temperature on the outlet side of the desuperheater is effected by means of an automatic valve in the line between the drum of the desuperheater and the auxiliary drum. Throttling down on this valve prevents the flow of steam to the auxiliary drum, and thus retards the flow of water into the space around the tubes of the desuperheater. This in turn reduces the effective cooling surface in the desuperheater and raises the outlet steam temperature. Conversely, if this valve is wide open the tubes of the desuperheater are completely immersed.

After the 400-lb. steam passes through the desuperheater it is reduced in pressure through valves of the turbine-control type. Two valves are used to permit good regulation over a wide range of steam flow. They are set like primary and secondary turbine-control valves; one valve passing all the steam until its capacity is almost reached, when the second begins to open.

The reducing valves are regulated automatically by controllers which are tied in with the automatic combustion-control system. The control is so arranged that as far as the 400-lb. boilers are concerned the tie line acts as a turbine, and as far as the 300-lb. boilers are concerned it acts as additional boilers. Thus if No. 4 turbine is suddenly tripped out, the reducing valve opens and feeds steam into the 300-lb. mains. The combustion control and the tie-line control work together to regulate the amount of steam generated by each plant in accordance with a predetermined ratio. If the turbine is started up with the tie line feeding into the 300-lb. mains, the reducing valves will close as the load is increased on the unit. When the load on No. 4 becomes such that the rate of steaming on the 400-lb. boilers exceeds the predetermined economical ratio, the valves will close and all the steam generated by the 400-lb. boilers will be used in No. 4 turbine.

Four 2292-hp. boilers designed for 400 lb. and 250 deg. superheat are installed to supply the steam to this unit. They are 44 tubes wide and 20 high, with an interdeck superheater set above the fifth row of boiler tubes. The whole of the rear wall is protected by a water screen made up of boiler tubes set on 7-in. centers. This screen extends well down into the ashpit, that part below the fire line being protected by cast-iron blocks carefully fitted to the tubes to insure good heat transfer. The side walls are also protected by similar water screens, but here construction difficulties required a slightly greater average distance between tube centers. The furnace side of these tubes at the fire line is protected by carborundum blocks. The front wall of the setting is lined with carborundum. The lower rows of boiler tubes are exposed directly to the radiant heat of the furnace throughout their whole length. The two lower rows of tubes are placed in line vertically to provide a slag screen. For removing slag, small doors are provided in the rear wall just under the top water-screen header. A steam lance used through these doors when the boiler is at low ratings very effectively breaks off the slag which adheres to these tubes.

The boilers are fired by 14-retort 39-tuyere underfeed stokers. In order to burn out the combustible in the refuse to the best ad-

vantage, the ashpit was made 30 in. wide and approximately 6 ft. deep. Air under separate control can be admitted to both the front and rear of the pit, and the pit is slightly wider at the bottom than at the top to minimize any tendency of the refuse to bridge. The stoker windbox is divided into 8 zones with separate damper control for each to assist the operator in maintaining the proper rate of combustion in various parts of the stoker. These are particularly useful in bringing a boiler up and in banking.

As the former type of steam-actuated agitator has been more or less messy due to steam leaks and its rather awkward location, a new type of agitator driven by the clinker-grinder motor was developed for these stokers. The driving mechanism is installed alongside the clinker-grinder drive, and the connecting levers are placed below the boiler-room floor.

Immediately above the boiler-outlet dampers are placed plate-type air preheaters. In order to get in the surface deemed advisable the plates are spaced on $\frac{1}{2}$-in. centers—much closer than has hitherto been the practice in this country. The preheaters of each boiler are built in two entirely independent units. Therefore either may be dampered off for cleaning while the other is in operation. The gas from each preheater passes through a cinder catcher to an induced-draft fan and thence to the main flue serving four of the 300-lb. boilers and four 400-lb. boilers. A division plate running the whole length of the flue separates the gases from the two rows of boilers.

Due to the very limited space available in the boiler room it was impracticable to install individual hot-air ducts from the preheater to the stoker of each boiler. Accordingly a common hot-air duct running the length of the boiler room at the level of the preheaters to pick up all the hot air, and then running down to the basement and the length of the boiler room again to distribute the air to the stokers, was necessary.

To protect against loss of air pressure in the event that the motor driving one fan trips out, and more particularly to guard the fan attendant against a back draft of dangerously hot air, automatic dampers were installed between each forced-draft fan and the main hot-air duct. These can remain open only when there is a flow of air from the fan to the hot-air duct.

The forced-draft fans discharge directly into the air preheaters, one fan being installed for each preheater unit. The induced-draft fans are located above the main flue and discharge downward into it. All of the fans are driven by 2300-volt wound-rotor induction motors, the resistors for which are located on a separate platform between the levels of the two types of fans.

A cinder catcher of recent design is placed in the inlet duct to each induced-draft fan. These consist of a series of eliminator plates. Their advantage over the older type installed in the 300-lb. part of the boiler house lies in their lightness, compactness, and absence of water.

Tight air ducts and gas passages are extremely important with preheated air, especially when the air-duct pressures are as high as those at Hudson Avenue (approximately 12 in. of water at full load); accordingly all the duct work installed for the 400-lb. boilers was fabricated with welded joints. The duct insulation is made fast to a metal framework built up outside of the expansion stiffeners, the metal framework being secured by means of clips welded to the duct. This construction permits the duct to expand without in any way cracking the hard finish on the insulation. It also makes a neat appearance.

The piping was fabricated from seamless steel tubing, and all high-pressure joints and valves 1 in. in diameter and larger are

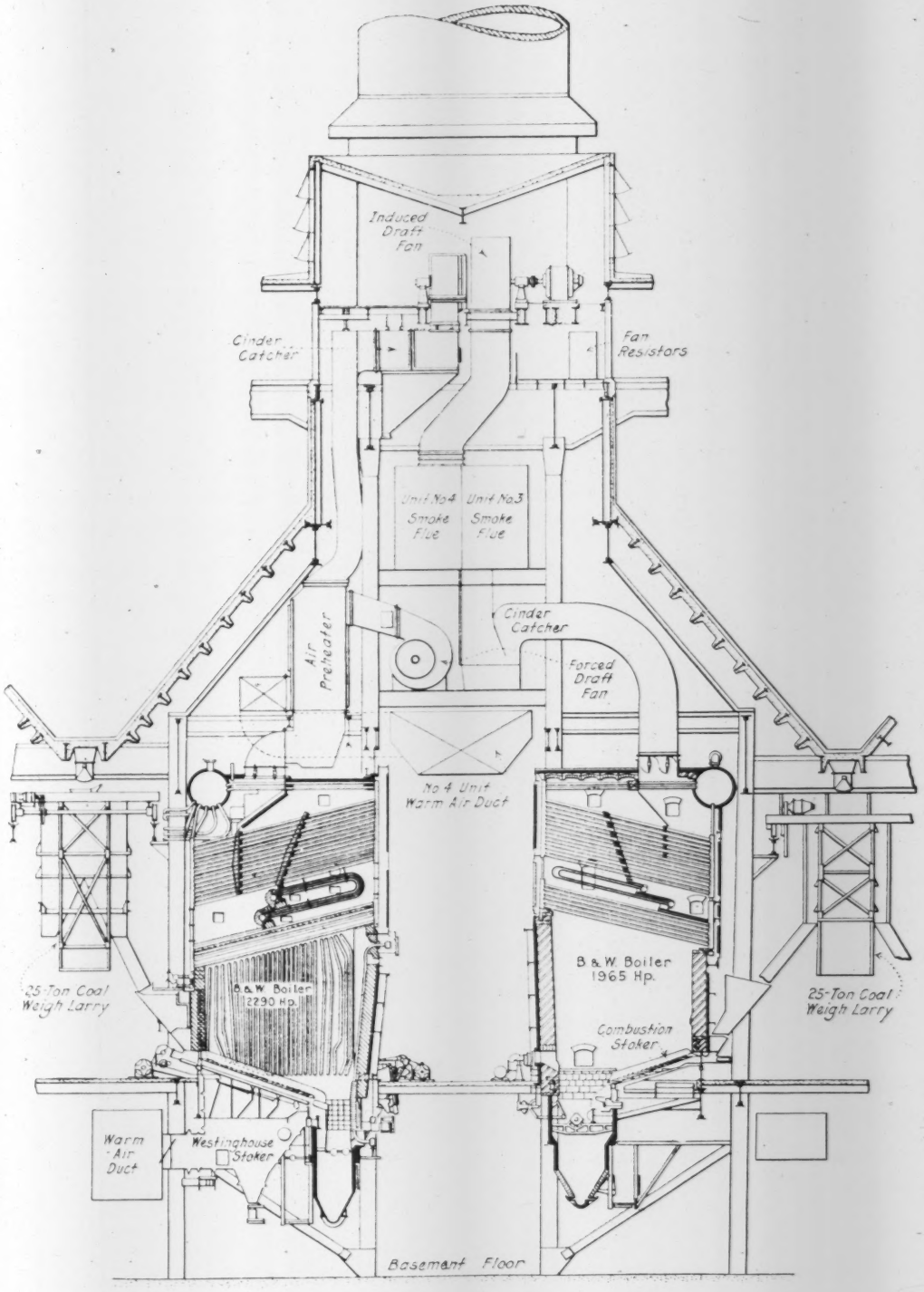

FIG. 2 CROSS-SECTION THROUGH BOILER HOUSE

flanged. The flanges are of the Van Stone type designed in accordance with the proposed A.E.S.C. standards for 600 lb. working pressure. Heat-treated alloy-steel studs threaded their entire length and soft gaskets are used on all high-pressure flanged joints.

Fig. 2 shows a cross-section through the boiler house at the No. 3 and No. 4 row of boilers.

OPERATION OF THE 300-LB. SECTION, UNITS 1, 2, AND 3

In the first few months of operation attention was centered on getting the apparatus to function properly and getting the personnel trained. After this had been accomplished and the operating instruments, many of which had been delayed due to the press of absolutely essential work, were installed, more attention was given to thermal efficiency.

There are installed enough meters, pressure recorders, and temperature recorders to show the performance of each important piece of apparatus. The performance of each turbine, condenser, heater, and boiler is computed every day, thereby directing attention to any apparatus which shows a decrease in efficiency.

The efficiency of the turbine-room apparatus is practically fixed by the design, so that there is very little the operator can do to alter it. The best he can do is to keep it clean and in good repair. To this end the turbines are thoroughly overhauled once a year during the off-peak period. At the same time the condensers, pumps, and other auxiliaries are carefully overhauled. The condenser vacuum, of course, requires constant attention. Aside from keeping air-removal apparatus in condition and air leakage to a minimum, the only factor affecting efficiency under the operator's control is condenser cleanliness. The circulating water at Hudson Avenue is contaminated by sewage, and the water side of the tubes is quickly coated with slime and mud. Many schemes for removing this deposit have been tried. The most effective one, that of forcing rubber plugs through the tubes at frequent intervals by water pressure, has been adopted. One crew of men working on the 12 to 8 watch is continuously employed at this work. In this way all of the tubes in each condenser are cleaned before the deposit has had time to build up to an extent which would materially impair vacuum and make cleaning difficult.

The water-rate curves of all three of the turbines in the 300-lb. section of the station are practically identical, so no special loading schedules are necessary.

The feedwater heaters are self-regulatory, the steam bled to each heater being a function of the amount of condensate flowing through the tubes and the pressures in the turbine extraction lines. Therefore there is nothing the operator can do to effect heater economy except keep them clean, properly vented for air removal, and the condensate-removal apparatus in order.

The efficiency of the station is therefore made or lost in the boiler room. But in order to get the boiler efficiency where it should be—and keep it there, which is much more difficult—it is first necessary to know just where the preventable losses are and the magnitude of each. The importance of this makes a somewhat detailed description of the methods worth while.

All of the coal hoisted is weighed on automatic track scales on the coal road between the crusher and the bunkers. The coal is again weighed in the lorries as it is dumped into the stoker hoppers. The amount fed to each stoker is separately recorded. The heating value of the coal is determined from samples taken from the stoker hoppers. Thus a very accurate daily record of the heat input to each stoker is kept.

In order to insure that these records are accurate, a number of checks are made. The calibration of the track scales is verified daily by weighing a test car on them. This test car consists of a sheet-iron box filled with lead weights, sealed up, and mounted on trucks. Its weight equals the weight of a coal car loaded to average capacity. So long as the scales indicate the same day-by-day weight for the test car, calibration in the range which is important must be correct.

The lorry scales are checked periodically by suspending test weights from the hoppers.

Twice a month the amount of coal in the bunkers is estimated, and the total coal weighed by the track scales is checked against the total lorry weights. To minimize errors in bunker estimates, the bunkers are filled on these dates whenever it is possible to do so.

The boiler output is determined from the boiler meters. These also show the flue-gas temperature, steam temperature, and stoker speeds for each boiler. These meters are relied upon for indicating the proper ratio of coal to air, but only as secondary standards. They are calibrated once a week by means of an Orsat.

It is therefore known with a high degree of accuracy just what each important piece of apparatus is doing every day. These results would be of only academic or historic interest, however, unless they were known to the men directly in charge of the apparatus—and known quickly. Accordingly a meeting lasting about half an hour is held every afternoon to discuss the previous day's results. This meeting is attended by the station superintendent, chief engineer, 1st and 2nd assistant chief engineers, chief boiler-room engineer, and station test engineer. The latter, who has prepared the record of performance, is in a position to point out any apparatus which is not functioning as efficiently as it should. The others, with the past day's work fresh in their minds, are able to explain any unusual operating conditions. If lack of efficiency cannot be satisfactorily accounted for by unusual conditions, the trouble is diagnosed as accurately as possible, and steps are at once taken to correct it. These meetings are a great benefit to station economy, as they bring out the need for attention to any part of the plant and create discussion of the problem by those most familiar with the operation of that piece of apparatus. After a means for correcting the trouble is decided upon, every man knows what part each one is to do.

But these men alone cannot hold the plant efficiency up; it is necessary to keep up the interest of the stoker attendants. To this end the coal rate and the B.t.u. rate per kw-hr. obtained on each watch is posted in the boiler room on the following day. In addition, the boiler efficiency for each day and the names of the stoker attendants working on that boiler are posted on the boiler-control panels. In this way each of the boiler-room operators knows how efficient the previous day's operation was and just what part he played in obtaining that efficiency. This creates a friendly spirit of rivalry and encourages each man to be on the alert to report any condition which would impair the efficiency of his boilers.

The system of combustion control employed has contributed to the maintenance of boiler efficiency and is worthy of a short description.

The stokers and forced-draft fans of the 300-lb. boilers are driven by variable-speed direct-current motors. Power from these motors is supplied by motor-generator sets located in the switch house some 200 ft. away. They operate on the Ward Leonard system—that is, the field strength of the generators is regulated to give the voltage at the motor terminals necessary to the speed required of the motors. This system permits very accurate speed control in a very great number of small steps. This regulation, together with the windbox damper and the boiler-uptake damper regulation, is accomplished by means of controllers which obtain their actuating impulses from a master controller. The master in turn obtains its actuating impulse from the steam pressure. Thus the load changes are taken on all boilers, the steam pressure kept constant within about three pounds, and the proper ratio of fuel to air maintained. The automatic control is on the job all the time, checking up on the amounts of fuel and air every time there is a change in steam pressure. This leaves the stoker attendant with more time to watch the fuel bed and the ashpit. It relieves him of much of the manual work and encourages more headwork.

The boilers of No. 4 unit are now being equipped with similar automatic control. In the meantime they are operated on centralized manual control. In the combustion-control room on the boiler-room floor are located remote speed control of the forced- and induced-draft fans, ammeters in the leads of each of the fan motors, draft gages, a steam-pressure gage, a forced-draft duct-pressure gage, and a load indicator. The operator here regulates the drafts to maintain steam pressure. The load is distributed equally among the boilers, each taking its own share of any load changes. The stoker attendants are relieved of all controls except those directly affecting the conditions of the fuel bed. That is,

they are only concerned with the stoker speed and operation of the clinker grinders, agitators, and sectionalizing dampers in the wind-box.

Similar manual controls are provided in this same room for the 300-lb. boilers. In the event of the automatic control being out of commission the 300-lb. boilers are controlled manually as described above. To guard against loss of pressure in the forced-draft duct due to failure of the automatic control, or failure of a motor-generator set supplying the fans of the 300-lb. boilers, two motor-generator sets are kept running. One is on automatic control, with the fans which it drives carrying the bulk of the load. The second is on manual control, with the fans it drives running at low speed and ready to pick up load at once in case of trouble.

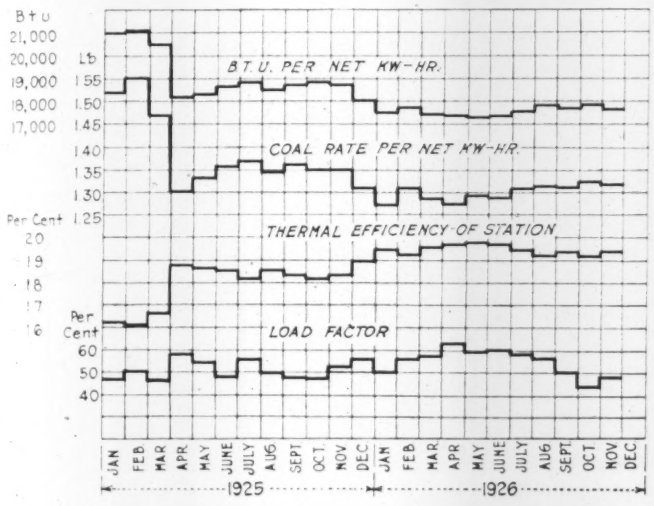

FIG. 3 STATION PERFORMANCE FROM JANUARY, 1925, TO NOVEMBER, 1926

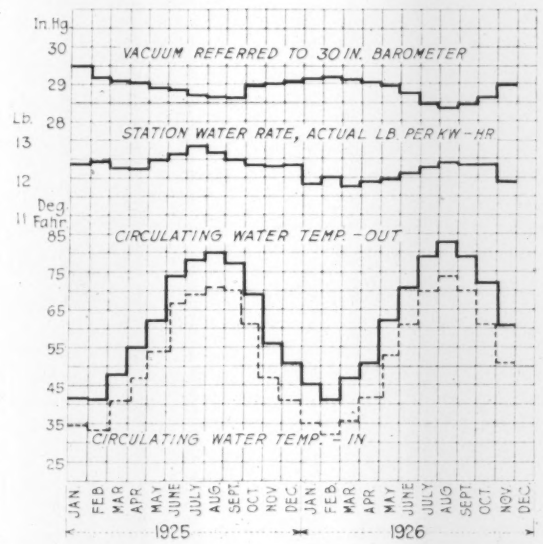
VACUUM REFERRED TO 30 IN. BAROMETER
STATION WATER RATE, ACTUAL LB. PER KW-HR
CIRCULATING WATER TEMP. - OUT
CIRCULATING WATER TEMP. - IN
1925
1926

FIG. 5 TURBINE AND CONDENSER PERFORMANCE FROM JANUARY, 1925, TO NOVEMBER, 1926

As Hudson Avenue is the most efficient station on the system it gets the bulk of the load. But as the system is mainly a lighting one, with very little 24-hour power load, there is a deep and extended valley in the load curve over the early morning hours. During these hours the load drops as low as 25,000 kw., the normal peak on the 300-lb. section of the station being 125,000 kw. In order to carry this peak efficiently it is necessary to keep every available boiler on the line. From the first week in October, to the first week in January (the peak-load season), eleven of the twelve 300-lb. boilers were steaming every day at the peak, except on Sundays when the load did not justify more than ten. The twelfth was kept out for cleaning for four or five days, after which it was again put in commission and the boiler with the highest flue-gas temperature taken out.

Annual internal boiler cleaning commences just after the peak-load season. This requires about three weeks per boiler and permits carrying ten steaming boilers every day at the peak.

During the early-morning watch it is not the practice to bank boilers in the ordinary sense of the word. The rating is reduced on two boilers at a time, long enough to clean off and inspect the extension grates and to remove the slag from the lower row of tubes, if the latter is required. If no grate repairs are necessary this work is completed before the rating has dropped below 30 or 40 per cent. In this way the banking loss and the clinker formations due to banking are kept to a minimum.

The slag formation on the lower rows of tubes caused considerable trouble when the plant was first started up as there was no

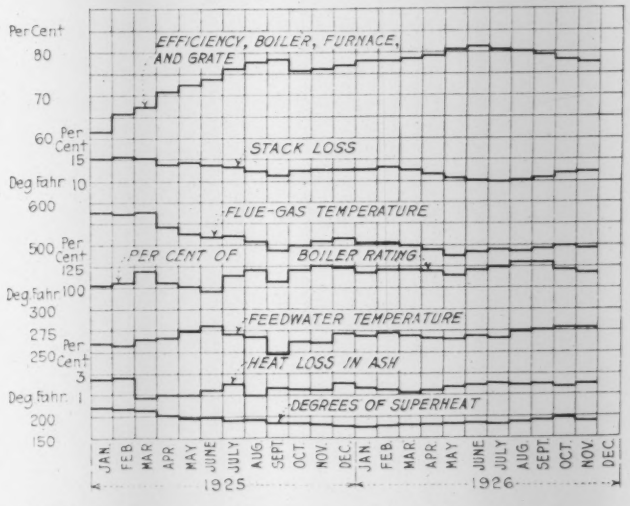

FIG. 4 BOILER PERFORMANCE FROM JANUARY, 1925, TO NOVEMBER, 1926

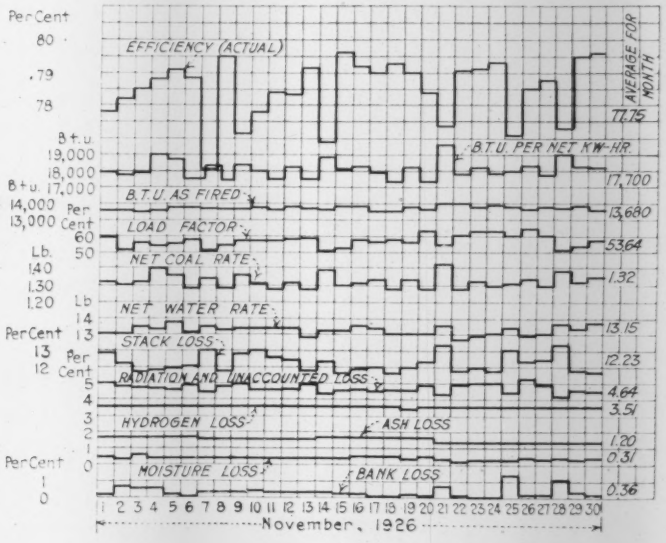

FIG. 6 DAILY STATION PERFORMANCE FOR NOVEMBER, 1926

convenient method of removing it. It was then necessary to take the boiler out long enough for a man to get into the furnace and remove the slag with a steam lance. Doors are now installed in the rear setting wall just below the lower row of tubes. This makes it a comparatively easy matter to blow the slag off with a steam lance while the boiler is operating at low ratings. Troubles were experienced with high excess air at the lower ratings. These have been largely overcome by very careful attention to the boiler settings. The customary construction of sheet-iron lagging over the nipples between the upper and lower deck of boiler tubes was removed and tee tile backed up by asbestos millboard fitted in to make a much tighter job. Other smaller leaks which were difficult to reach were stopped by means of a cement gun, using a mixture of fireclay and hytempite.

AUXILIARY DRIVES

No description of the installation or operation at Hudson Avenue would be complete without some mention of the auxiliary drives. All auxiliaries with the exception of three stand-by steam feed pumps, are motor-driven. Motors 50 hp. and larger operate at 2300 volts, those smaller than 50 hp. at 440 volts. All are started by throwing directly across the lines without the intermediary of any starting equipment. Starting is further simplified by the installation of push-button control on the 2300-volt motors. Thus to start a motor, all the attendant has to do is push the starting button near by, which closes the breaker in the switch house and brings the auxiliary up to speed.

In order to safeguard continuity of service on the auxiliary bus, three sources of supply are provided for the auxiliaries of each pair of main units. A 6000-kva. house transformer fed from the 27,000-volt station bus normally supplies the power. Backing up the transformer is a frequency changer which floats on the auxiliary bus. The 25-cycle end of this unit is an induction motor. This motor draws power from the 25-cycle system only in the event of trouble to the auxiliary supply which depresses the frequency. The third source is a house turbine. The house turbines exhaust to condensers through the tubes of which the condensate from the two main units is pumped as circulating water.

The system of auxiliary drive has been so reliable that it is not deemed necessary to run the house turbines. They are therefore held in reserve and operated only enough to insure their availability on demand.

The electrically operated coal towers at Hudson Avenue have also been very satisfactory. They have exceeded the design figures in capacity and performance. Except for rope renewals, the maintenance costs have been practically nothing. Power at 2300 volts is supplied to each tower, where a motor-generator set converts the energy for the hoist machine to direct current. Ward Leonard control with regenerative braking allows very flexible and very economical operation. The towers are high and hence high bucket speeds are essential, the distance from high water to hopper being 185 ft.

OPERATING RESULTS ON 300-LB. SECTION

Fig. 3 shows the station performance since January, 1925. The best thermal efficiency, 19.78 per cent, corresponding to 17,200 B.t.u. per kw-hr. and a load factor of 58 per cent, was obtained in May, 1926.

Fig. 4 shows the boiler performance for the same period. The best month was June, 1926, when an average of slightly over 81 per cent was obtained. The average boiler rating in that month was 120 per cent, and the flue-gas temperature averaged 480 deg.

Fig. 5 shows the station water rate, the vacuum, and the circulating-water temperatures for the same period. This curve shows what wide variations in vacuum and hence station water rates are traceable to the temperature of the circulating water.

Fig. 6 shows the daily station performance for one month.

At the present writing No. 4 unit has been in operation for about one month, but as yet only three of the four boilers have been put in commission, and adjustment and tuning up of the apparatus have not been completed. No tests have been made, and the operating results with station instruments are as yet too uncertain for publication. However, it seems safe to predict that the coal rate of this unit will very closely approach 1 lb. per net kw-hr.

Progress in Marine Steam Machinery

A GOOD example of modern geared-turbine arrangement is that which was fitted in the twin-screw Orient liner *Orama*, built by Messrs. Vickers, Ltd., in 1924. Each set consisted of three turbines geared by single reduction to the propeller shaft with three pinions gearing into a common wheel. Special attention was paid in this installation not only to the efficiency of the main turbines, but also to economy in the fuel consumption for the auxiliary machinery, with the result that an overall fuel consumption was obtained of 0.785 lb. of oil fuel per shaft horsepower-hour for all purposes. Several other vessels of similar type have been equipped and have realized a similarly low fuel consumption.

The figures given elsewhere do not represent the whole of the improvement in economy effected by the introduction of gearing, since with gearing the propeller efficiency has been increased. In fact, prior to the introduction of gearing comparative tests of turbine propellers were made by the Parsons Marine Steam Turbine Co. in a vacuum tank, which indicated an improvement in propeller efficiency in the neighborhood of 12 per cent with low-speed propellers instead of the high-speed propellers previously adopted with directly coupled turbines. The advantages of gearing were not, however, confined to the vessels of slow and moderate speed, for which it was primarily intended. Its use soon became general for fast cross-channel steamers and even in high-speed war vessels, leading to improved economy both at full power and at cruising speed as well as increased facility of overhaul on account of the smaller size of the turbine units. With the use of additional cruising stages, it has been estimated that the cruising radii of naval vessels have been increased by some 40 per cent owing to the introduction of mechanical gearing.

The use of mechanical gearing having enabled turbines in marine propulsion to be designed with the maximum efficiency of conversion of the available energy of the steam, it is now being sought to realize the considerable improvement which is attainable by the use of higher steam pressure.

A pioneer installation of high-pressure machinery was fitted last year in the Clyde steamer *King George V*, having a power of 3500 shaft hp. on two shafts, a boiler pressure of 550 lb. per sq. in., and the steam superheated to 750 deg. fahr. It will be clear that the economical effect of adopting high pressures would have been considerably greater in an installation of large power. The experiment on this vessel, however, was not only made in order to demonstrate a higher efficiency but to explore the practical application of high temperatures and water-tube boilers to marine work, and also to ascertain what practical difficulties, if any, had to be overcome in this connection. In order to limit the variants as far as possible to the main engines and boilers, the auxiliary machinery is of the usual type. The steam for the auxiliary engines is taken from the superheated-steam drum through an internal pipe in the saturated-steam drum, by which means its temperature is reduced. Thence it is led through a reducing valve, and supplied to the auxiliary steam range at a pressure of 200 lb. sq. in. and a temperature about 450 deg. fahr., being thus only slightly superheated. These engines exhaust at a pressure of 5 lb. per sq. in. above atmospheric, and the exhaust steam is condensed in a feed heater of the surface type, thereby raising the temperature of the feedwater to about 200 deg. fahr. It then passes to an additional high-pressure feed heater utilizing steam tapped off from the turbines, which raises its temperature to about 300 deg. fahr.

After the completion of the builders' trials, in which the specified speed and power were easily fulfilled, the *King George V* was put immediately on service on the Clyde, and ran regularly for three weeks to the end of the season. The vessel was then placed at the disposal of the builders for consumption trials. Calibrated measuring tanks were placed on deck, and connections made in such a way that a measurement could be taken both of the steam consumption of the turbines only and of the auxiliaries simultaneously.

The figures obtained agree closely with the results anticipated for this vessel, bearing in mind the small power per shaft and the shortness of the blades of the high-pressure and first intermediate turbines, and confirm that in larger powers the gain of efficiency claimed for higher pressures and temperatures will be obtained. The experiment has shown that there are no difficulties in the way of such installations which cannot be met by suitable provision. (Hon. Sir Chas. A. Parsons, R. J. Walker, and Stanley S. Cook in *Engineering*, vol. 123, no. 3184, Jan. 21, 1927, pp. 87–90.)

Layout and Operation of the Electrical System of the Brooklyn Edison Company

Layout and Operation of System Comprising 25-Cycle Transmission at 6600 Volts to D.C. Substations, 60-Cycle Transmission at 27,000 Volts to A.C. Substations, the Two Tied Together by a 35,000-Kw. Frequency Changer

By E. C. M. STAHL,[1] BROOKLYN, N. Y.

TO COMPLETE the picture of power generation in Brooklyn, the mechanical operating features of which have been presented in the papers by Messrs. Houghton, Cox, Holmes, and Cook, an outline of the layout and operation of the electrical system should be included.

The Brooklyn Edison System comprises two distinct types, the older one being the familiar 25-cycle transmission at 6600 volts to the direct-current substations, of which there are seventeen, and the newer a 60-cycle system comprising a 27,000-volt transmission to alternating-current substations, of which there are eleven. The 25-cycle and 60-cycle systems are tied together by a 35,000-kw. frequency changer, both sides of the machine being of the synchronous type. This machine is considered a part of the transmission system, acting as a tie feeder and being capable of transmitting load in either direction. A schematic diagram showing the essential layout of the electrical system is shown in Fig. 1.

Fig. 2 is a map of Brooklyn showing the location of generating stations and substations.

To meet the requirements for continuous and reliable electrical service to our customers, not only must a reliable source be provided but an arrangement of generating-station buses, transmission feeders, substation equipment, distribution feeders, and mains must be arranged to insure that power will reach the customer, even though a bus, feeder, or substation equipment is lost.

Reliability and continuity of service in the 25-cycle transmission system are obtained by the well-known procedure of having a double set of buses in the Gold Street generating station and a number of transmission feeders to each substation starting from diverse sections of the generating-station bus. There are also tie feeders running between some of the 25-cycle substations and 6600-volt customers. With the exception of the Coney Island substation and two small industrial substations, all of the 25-cycle to d.c. substations supply the power to a common three-wire Edison network, some of which has been in the ground since 1888; the latter consisting of the original Edison tube. The d.c. network is backed up and stabilized by storage batteries located in d.c. substations.

The operating schedule for rotary converters and motor-generator sets which supply the d.c. system is based on the same principles that were laid down for the operation of equipment in the generating stations; so that in case of the disabling of the largest unit in operation, the other units will automatically be able to take care of the load. The storage batteries are kept floating on the line at all times and only discharged in the case of an emergency. They do not operate as formerly, or as is common practice in railway substations, by regulating the load factor on the rotating machines.

In the last few years a quarter of the 25-cycle load has been taken over on the 60-cycle system, and this load is now being held to a peak of about 70,000 kw. by changing over from time to time a district having the equivalent loading of the natural increase. The 25-cycle system serves the industrial and business section of the city, although an alternating-current service is being superimposed in the same territory to take up new load.

The 60-cycle transmission system, which now takes care of three-quarters of our net generated output, is of particular interest because it is laid out quite differently from the usual metropolitan design. The big problem of the modern electrical system with great concentration of energy in a single plant is to provide means for handling the terrific forces which seek an outlet in an apparatus or cable failure. The system must be so designed that the rush of energy into the fault can be checked before more than local damage is done, and so that it can be reduced to an amount which a circuit breaker can interrupt with safety. It must also be so laid out that damaged feeders or transformers may be immediately automatically disconnected from the system without disturbing the continuity of supply from the generating station to the distribution feeders.

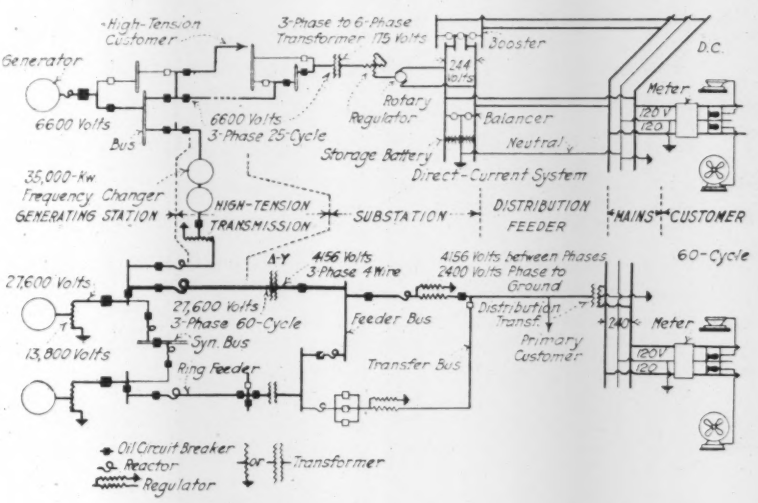

FIG. 1 ESSENTIAL LAYOUT OF THE BROOKLYN EDISON COMPANY'S ELECTRICAL SYSTEM

The way in which these essential elements have been incorporated into the Brooklyn Edison 60-cycle electrical system is easily visualized by referring to Fig. 1, which shows a schematic diagram of the essential elements of the electrical system. The method of limiting the flow of energy into a fault is by inserting choke coils in the feeders which permit no more than 20 times their normal current to flow into a fault regardless of the amount of generating capacity on the bus. The latter amount of energy is about 50 per cent of the rated interrupting capacity of the circuit breaker. The bus sections are fed directly by only one generator; the generators being tied together through 10 per cent reactors, which together with the reactance of the generators and their autotransformers, limit the flow of current into a dead short-circuit on the bus (could this ever occur) to about ten times the capacity of any one generator, or 700,000 kva. The circuit breaker which would be called upon to interrupt this flow of energy is rated at 1,500,000 kva. Even though circuit breakers of greater interrupting capacity were available, the use of choke coils is highly desirable in order to protect the generators against excessive shocks due to great overloads, and also to protect the service against big drops in voltage which would occur were no choke coils used. In the substations the question of interrupting capacity is not as acute as in the generating stations. The maximum interrupting capacity used in the substations is 500,000 kva.

[1] Assistant Superintendent, Hudson Avenue Generating Station, Brooklyn Edison Co. Mem. A.S.M.E.

Presented at a meeting of the Metropolitan Section of the A.S.M.E., New York, January 31, 1927.

From the following discussion of Fig. 1, it will be seen that the foregoing elements have been incorporated in the 27,000-volt system. The normal path of the electrical energy from the generator to the customer is as follows:

Generated at 13,800 volts, it is stepped up by a direct-connected autotransformer to 27,600 volts, passes through the generator switch to the generator bus, through a selector switch to a feeder-group bus through the feeder switch, feeder reactor, and feeder to the substation, where it enters a 10,000-kva. transformer direct without any switching; passing through the transformer where it is changed to 4156 volts 3-phase 4-wire power, through a circuit breaker to the substation feeder bus; through the feeder switch, reactor, and regulator to the distribution feeder and transformers in the manholes.

An alternative source of supply at Hudson Avenue is taken from another generator, through the generator reactor, synchronizing bus, another generator reactor, and to the original generator bus.

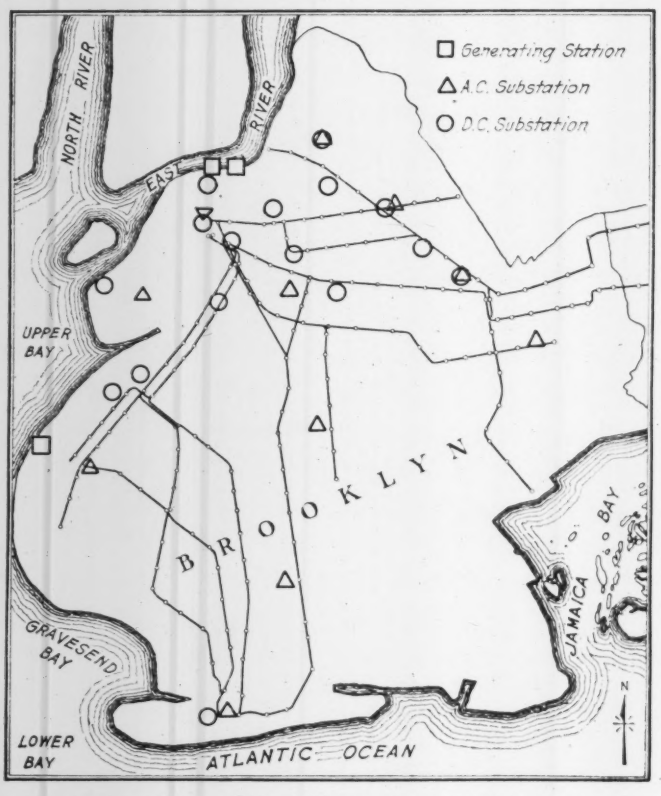

FIG. 2 MAP OF BROOKLYN SHOWING LOCATION OF GENERATING STATIONS AND SUBSTATIONS

Should the direct feed to the substation transformer become disabled, an alternative feed to the substation is already available and tied in. This feed leaves the generating station from a different feeder group and feeds a bus in the substation to which a "ring" or stand-by transformer is connected. This bus has additional sources of feed as shown on the diagram. The ring transformer feeds a synchronizing bus in the substation which is connected through a reactor and circuit breaker to the feeder bus and is continually floating on this bus ready to pick up the outgoing distribution-feeder load in case of the loss of the direct feed. Should a feeder circuit breaker, regulator, or reactor, or feeder bus become disabled in the substation, an alternative means of taking care of the outgoing distribution feeder is provided for in the transfer bus, which is fed from the synchronizing bus.

The 60-cycle distribution-feeder circuit breakers are equipped with automatic reclosing features so as to insure reëstablishing service as quickly as possible. On the first short-circuit they trip out and reclose instantaneously. If the trouble still exists, they will trip out again and wait 30 sec. and then automatically reclose. Should the trouble still persist, they will open again and remain open for 60 sec. and then again reclose. Provision is further made so that only the individual phase that is in trouble need be left out until repairs can be made. The good phases can be kept alive individually. In the newer stations this is accomplished by having single-pole breakers on the feeders themselves; in the earlier 60-cycle stations this is done by putting the good phases on the transfer bus.

The protection of the 27,000-volt system is accomplished by the application of inverse definite time induction relays of the overload and directional overload type, with certain applications of differential protection to the generator windings and the synchronizing bus.

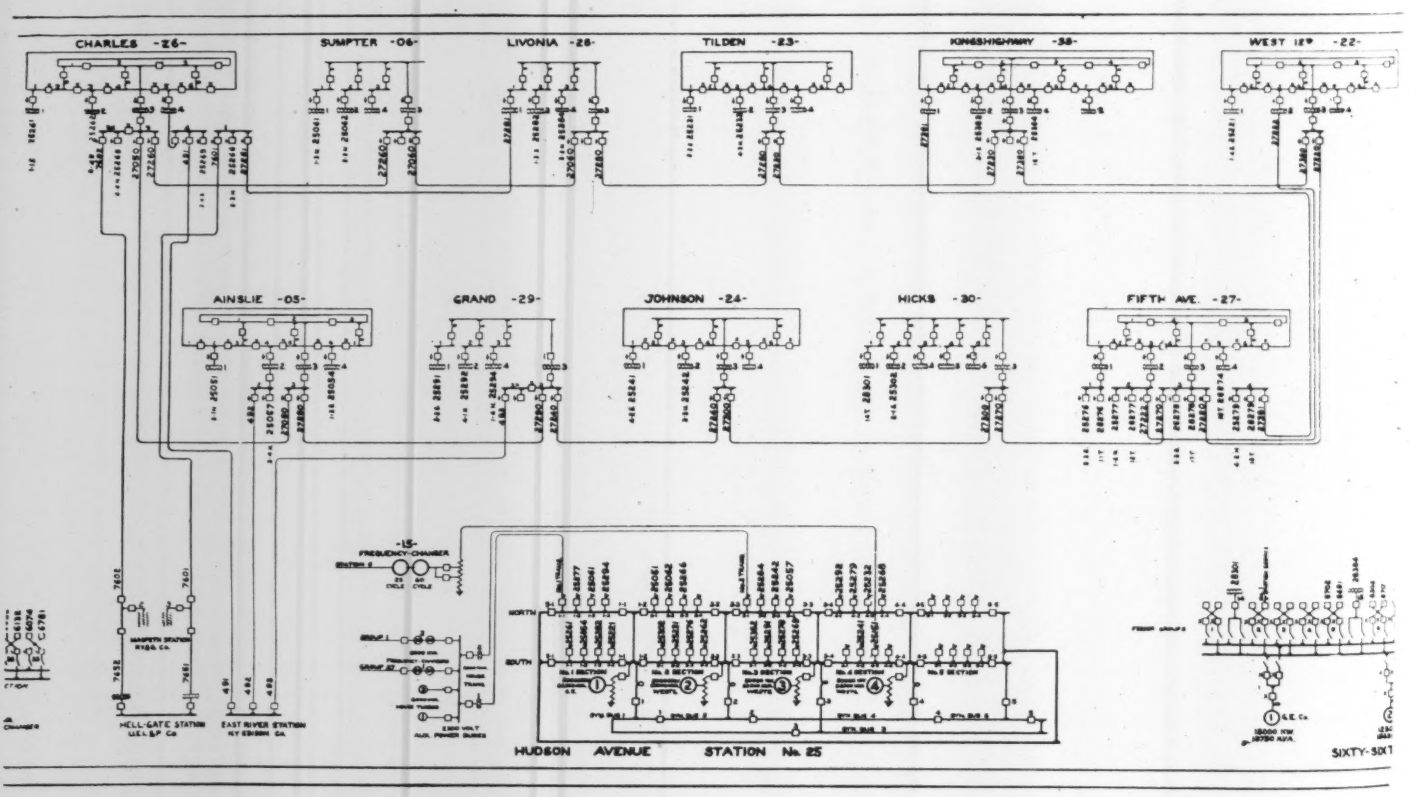

FIG. 3 A SECTION OF THE SYSTEM OPERATOR'S DIAGRAM

System Operation

The actual responsibility for placing generating units in and out of operation and for the operation of the transmission systems, all high-tension switching, and for the protection of workmen anywhere on the system, is lodged with the System Operator.

During normal operation he is guided in the selection of particular units by the schedules which have been prepared, as described in the other papers, but under emergency conditions of operation his first consideration is continuity of service, though, if possible, he will order the units on in accordance with the predetermined schedule. To keep in touch with all parts of the system, the System Operator is provided with a special telephone board with direct communication to each of the generating and substations and the larger power customers. In addition to this there is a unique signal system to all of the 25-cycle d.c. substations.

For quickly visualizing normal operating conditions and special conditions on the system, a system diagram is provided in convenient size and form which can be readily altered to show any change on the system. A section of this diagram is shown in Fig. 3. The great majority of all high-tension switches are normally closed and no special indication of this is made on the chart. An open switch, such as a generator switch or a tie-feeder switch which is open but available, is indicated by a white button; a switch which is open for some special purpose is indicated by a red, yellow, blue, or green button, depending on the code color of the character of the hold-off. Thus all unusual conditions are immediately apparent and localized.

Due to the high degree of reliability of the modern relays and the fact that high-tension switches are not closed again after trouble except on an order from the System Operator, an automatic indicating board was considered unnecessarily complicated and too expensive for the results that it could accomplish.

The System Operator's judgment is called into play in anticipating daily load conditions, which depend upon the weather and on the religious, business, and civic duties of the population. He must be continually alert to anticipate sudden storms, particularly in the summer time; or when we are called upon in emergencies by companies having ties with our system to furnish them additional power.

The diagram used by the System Operator gives the complete layout of the Brooklyn system, both 25- and 60-cycle. From it the statements made earlier in this paper can readily be visualized, particularly the grouping of the fundamental elements involved in the continuity of service in the 60-cycle transmission system and substations. It will be noted that each of the Hudson Avenue generators will normally feed two groups of four feeders each, and that each group of four feeders may select one of two generators. In addition to feeding group sections directly, each generator feeds into a ring bus through a reactor, so that all generators in operation may be tied together—but with sufficient cushioning effect between them to limit any destructive flow of power in case of trouble. The diversity of feeders from the Hudson Avenue buses to any one substation is easily traced out. The system of feeders and tie feeders constituting the substation ring may be considered as an emergency bus extended throughout the city, and the ring transformers which are floating on this bus but carrying very little load, have the same function as the storage batteries in the d.c. station, viz., they are continuously connected to the substation buses but are not called upon to deliver any power to the distribution feeders until the normal source of substation power is diminished, when they automatically pick up the excess load on the remaining substation transformers.

Wood Lacquer Finishes

Measuring the Depth of a Varnished Surface—Effects of Glues and Fillers on Lacquer—Use of the Cooper Hewitt Lamp in Evaluating Lacquers

FOUR papers were presented at the Wood Industries Session Tuesday morning, December 7, 1926, during the Annual Meeting of the A.S.M.E.: namely, Wood Finishing—A Glance Ahead, by F. L. Browne; The Technology of Wood Stains and Fillers for Use with Lacquer, by S. M. Silverstein; The Use of Wood Lacquer Finishes, by Walter S. Edgar; A Study of Varnish and Lacquer Finishes Exposed to Accelerated Breakdown Tests, by Paul S. Kennedy. A Safety Code for Woodworking Plants, by E. Ross Farra, was also presented. The session was presided over by Ralph E. Flanders, chairman of the A.S.M.E. Publication Committee.

Mr. Browne's paper dealt with wood finishing as an art, a science, and a branch of engineering; it pointed out that technical knowledge is the foundation of wood-finishing engineering, and also that there was a need for methods of measuring the service value of finishes; Mr. Silverstein discussed the importance of fundamental research work on the development of sound undercoating materials for use with lacquer, and progress in the development of non-grain-raising water stains and rapid-drying water-base fillers; Mr. Edgar's paper gave particulars regarding the preparation of wood surfaces for finishing and methods of applying pyroxylin lacquers that have proved successful in practice; and Mr. Kennedy gave results of comparative tests on wood blocks coated with varnish and with pyroxylin-base lacquer, and conclusions drawn therefrom. These papers were published in the Mid-November, 1926, issue of MECHANICAL ENGINEERING, pp. 1286–1296.

In a written discussion on Mr. Browne's paper, Carl L. Bausch[1] said that the "virgin field" of measuring results that Mr. Browne mentioned had been tampered with to some extent. A regular microscope would show quite nicely the depth of a varnished surface. With the use of vertical illumination it was possible to focus on the lacquer surface, and then to go through the transparent lacquer and focus on the wood surface, and by means of the graduated fine-adjustment button, to measure the movement from one layer to the other.

The most convenient outfit for doing this on small panels or sample pieces, Mr. Bausch said, was the metallographic microscope found in most testing and research laboratories. If a portable instrument which could be placed directly on a piece of furniture was desired for this work, it was very easy to rig up a special base. A small sub-stage lamp held by a bracket attached to the nose piece of this instrument furnished the illumination in place of the arc lamp used on the metallographic microscope, and gave fairly satisfactory results.

Thomas D. Perry[2] discussing the paper orally, said that his company had an interesting experience recently, on the question of wood finishes, which perhaps showed one of the needs of testing. One of their service engineers had told him that he had just had the task of finding the cost of finishing in a small plant. He had arranged with the foreman to finish four like units, one in ten minutes, one in twenty, one in thirty, and one in forty minutes, working purely from the cost basis. The manager had been able to select the cheapest and the best, but could tell nothing about the intermediate grades. The superintendent had picked the finish completed in the shortest time as being the best. The opinions of several other people had been so varied that his company had decided that for this particular product the cheapest finish was good enough—that the rest of them meant nothing to any one. If the plant people themselves could not tell where the added labor had gone, surely the public would not.

That, Mr. Perry said, was just a very crude example, but it showed

[1] In charge of Research and Engineering, Bausch & Lomb Optical Co. Mem. A.S.M.E.

[2] Director, Woodworking Division, Bigelow, Kent, Willard & Co., Boston, Mass. Mem. A.S.M.E.

that observation was a poor guide and that a better gage of measuring the value of finishes was needed.

After Mr. Edgar's paper on The Use of Wood Lacquer Finishes had been read, Mr. Perry inquired whether there were any organizations of wood-finishing manufacturers who were attempting to develop standards of either finishes or ingredients of finishes or procedure. He mentioned that the animal-glue manufacturers had worked out a series of standards.

Mr. Edgar replied that the American Society for Testing Materials had appointed a Lacquer Committee which was attempting to building up tests that might be used by the consumer rather than by the manufacturer. That committee was doing a lot of woodwork covering all possible uses of lacquer, but not of fillers, shellac, or varnishes. It was really two committees: one composed of those supplying raw materials used in the manufacture of lacquer; the other composed of the selection group, some of whom were manufacturers and some consumers.

In reply to C. H. Sisson[3] he said that the body referred to was the Finishers' Association. The first committee was composed of the manufacturers of raw materials. Lacquer differed from varnish, he explained, in that there were certain well-defined materials used in its manufacture. The second committee was set up to devise certain tests for finish lacquers, and was composed of manufacturers of lacquer and the users of lacquer. He stated that the second committee would welcome any user of wood-finishing material who desired to present any ideas as to the tests he would like to have set up.

Ernest Janssen[4] asked Mr. Edgar whether any manufacturers in the United States had ever made any inquiries regarding the application of lacquer in oriental countries.

Mr. Edgar explained that Japanese lacquer had been investigated to some extent in this country. It was generally accepted as being a combination of certain resinous material, and was not particularly satisfactory.

To the question of C. L. Davidson[5] in regard to what different effects the use of vegetable or casein glue had on lacquer, Mr. Edgar replied substantially that they were known only when the properties of the glue were known. There was no reason why lacquer could not be used over either vegetable or animal glue. Vegetable glue perhaps dried more slowly. It was usually put in solution with a caustic solution. Those properties ought to be considered when applying lacquer over it. In using the vegetable glue it might be necessary to give more time for drying and to be quite sure that an excess of caustic had not been used in its preparation. Excess glue also had to be cleaned off more thoroughly.

Mr. Perry made the observation that he had known a number of woodworkers and research men to ask where there was a standard, an accepted standard, which they could compel wood-finishing manufacturers to live up to in supplying materials. The answer had always been that if the user would specify what was to him a satisfactory standard, the manufacturer could tell how closely his material measured up to that standard. Manufacturers did not, however, have any generally recognized standard by which they could gage their material by weight, percentage, viscosity, or otherwise. This condition was admitted by some of the largest varnish makers in the country.

Mr. Perry suggested that here was an opportunity for these makers of wood-finishing materials to make a start toward establishing some kind of "hitching post" to which records could be hitched as facts were obtained.

Mr. Gutsohn asked what the relations of the ingredients—animal, vegetable, and mineral—were; that was, whether their mixing in finishes led to complications.

Mr. Silverstein replied that, generally speaking, it made absolutely no difference what the material was that was used under another material if there was no chemical reaction between them.

Whether casein, oil-base, or any other type of filler were used, sufficient time after application must be allowed for the coating to come to equilibrium, that was, come to a final state of rest. If the resulting residual film could not be attacked by the subsequent films, one would be on the safe side.

For instance, if an ordinary oil-base filler was used, care must be taken that the oil components were of the right type and sufficient time must be allowed for complete drying. The main thing to make sure of was that the film left behind was "dead" with reference to the film that followed. It made little difference whether the materials came from the animal, vegetable, or mineral kingdom.

Mr. Sisson said that Mr. Silverstein, as a chemist, had covered very beautifully the subject from the standpoint of chemistry and electricity. He had neglected, however, the mechanical factor of expansion and contraction. He took the opportunity to appeal to the Wood Industries Division to join with him and others in urging upon the owners of furniture, pianos, etc., a better understanding of the properties of wood with respect to expansion under temperature and humidity.

Mr. Silverstein said that while this might be done, it seemed to him that it was directly up to the woodworking industry to take an easier method of protecting their goods. It was surprising that they had existed so long without having perfected means for overcoming the changes in wood due to atmospheric conditions. It was scientifically possible to prepare wood so that it would be unaffected by any atmospheric changes within reason.

In discussing Mr. Kennedy's paper, Mr. Thompson[6] said that mention of the Cooper Hewitt lamp had brought to his mind an experience in separating the action of varnish and lacquer, and mentioned some of the limitations he had found. Particularly on the earlier lacquers it had been noticeable that sunlight, even through glass which removed some of the short waves, had a tendency to cause the lacquer to fade.

Direct sunlight testing had proved inconvenient because of the fluctuations of the weather, and because the material had to be exposed at just the right place. It was natural, then, to turn to an artificial source for rays to deteriorate the film. The Cooper Hewitt lamp had been tried on account of its ultra-violet rays. While it was flexible and covered a large range of short wave lengths, experience with it did not duplicate by a good deal the effect of direct sunlight.

It was disclosed that while a new Cooper Hewitt lamp began to affect the cellulose nitrate very soon after it was put in service, the spectrum began to deteriorate after a few hours. So far as Mr. Thompson knew, there was no method of ascertaining how soon that was going to take place, and so it left the Cooper Hewitt lamp a very uncertain factor.

Samples exposed to the weather were ordinarily protected with panels of transparent quartz, which would let through the short waves. The results, however, would not be exactly the same as when uncovered. There was a property in the sunlight which was injurious to cellulose nitrate, and which even transparent quartz would modify to some extent. Mr. Thompson therefore favored the use of direct sunlight, and if quartz plates were used, to stick right to them. He urged caution in trying to evaluate the results from the Cooper Hewitt lamp on cellulose nitrate; he favored the blue-flame arc as a more dependable test light.

Mr. Silverstein replied that he had had occasion to use Cooper Hewitt quartz lamps in four distinct industries. His experience had been that if the Cooper Hewitt quartz lamp said "No," it saved time. If it said "Yes," the finish was still subject to further experimentation with direct sunlight. Hence the Cooper Hewitt lamp really served a very valuable function in that it eliminated a lot of material and combinations that would fail only at the expense of a lot of time, whereas those particular materials that did stand up against quartz rays must be further investigated if they were going to be graded to some resistance.

Mr. Hopkins reported results with a recent style of Cooper Hewitt lamp. In running some tests on a pigmented lacquer enamel, when the lamp was a thousand hours old, in conjunction with the water and refrigeration tanks, he had produced a failure. This panel had been coated with a red oxide primer, three coats of surfacer, and three coats of lacquer enamel, and had deteriorated in 60 days. When the lamp was 2500 hours old, the same test was

[3] Engineering Department, Baldwin Piano Factory, Cincinnati, Ohio. Mem. A.S.M.E.

[4] Engineer, Eagle Pencil Co., New York. Assoc-Mem. A.S.M.E.

[5] Superintendent Electric Division, New York Central Railroad, New York. Mem. A.S.M.E.

[6] Meriden, Conn.

duplicated, and the same amount of checks was obtained. The panel deteriorated in the same way, in exactly the same length of time—that was, 60 days. Allowing for a decrease of lower waves, this was a very good check on this panel. It was found in comparison with roof exposures of these same panels that there was a factor of approximately 1 to 8. By using ozone in conjunction with the ultra-violet lamp, the factor was increased from 1 to 8 to approximately 1 to 18.

The research division of the New Jersey Zinc Company had found that by boosting up the voltage used with the mercury arc they were able to maintain the lower wave lengths which rapidly decreased after the first 1200 hours. They measured their lamps from time to time—that was, approximately every four or five days.

Mr. Hopkins reported that it had been disclosed by comparative tests that the mercury arc was very satisfactory, and that what was learned from the test with the mercury arc could be reproduced to a certain extent in comparative tests on roof exposure.

Better Ships for Less Money

The Various Kinds of Standards Used or Usable in Shipbuilding—Benefits to Be Derived from Sensible Standardization in Ship Design—Necessity for Conservatism in the Adoption of Standards

BY REAR-ADMIRAL GEORGE H. ROCK[1] (CC), U.S.N., WASHINGTON, D. C.

THE present general movement toward standardization in industry is the natural result of the forces which gradually and for a long time have been building up in that direction, although the first national organization of prominence with which I am familiar is the British Engineering Standard Association, instituted in 1901.

Every engineer who has handled large contracts which included projects having similar features has experienced the desire and felt the necessity of simplifying and standardizing in order to save time and cost and to insure a better product. Twenty-eight years ago in the Superintending Constructor's Office in which I was an assistant, in a large shipyard where several war vessels were under construction and a fairly continuous building program was expected, there was prepared a large bound volume, called "Standards," consisting of some two or three hundred sheets of fittings of all kinds entering into the construction of the vessels. These standards were specified by their symbols on the various working plans as they were developed for the different ships, and thus not only saved time in the preparation of plans and the fabrication of the fittings, but also insured the installation of a standard fitting wherever it was applicable. This of course was mandatory only in that one yard, but the data were used to some extent in other shipyards.

Similarly, in the same office, the filing of correspondence became so involved that necessity forced the working out of a subject filing system, intended to be applicable, and which it was hoped would be adopted, for all similar offices. The point intended to be brought out here is that the underlying idea was to simplify the procedure and to standardize the methods to save time and to promote accuracy and uniformity. These two incidents are cited only to illustrate the inference intended to be drawn from the earlier statement that isolated efforts toward standardization were being made in many places, but there was not much encouragement in the nature of a general acceptance or adoption by others.

Many branches of industry drift along aimlessly with an enormous quantity of spare parts and an excessive diversity of sizes and patterns for the same design for every-day pieces of apparatus. This means a vast amount of stock accumulated and turned over very slowly, with high costs of production. This was exemplified by an experience of mine in one of our large navy yards about 17 years ago, occasioned by the condition of the storehouses in which there was a very large accumulation of stock or fittings of all kinds, a large proportion of which had been turned in by various ships going out of commission or undergoing extensive overhauling over a period of several years. Due to lack of space or foresight, or bad management in some part of the organization, these fittings had not been kept segregated and they were in such quantities and in such a multitude of sizes and designs that it was the general practice, because it was considered cheaper and it certainly was much less trouble, to make a new fitting than to search out a suitable one in store.

An unused building was selected and hundreds of loads of these fittings were hauled to it, where they were sorted and stowed in suitable bins and on racks, shelves, etc., so labeled that any article could be found immediately. Complete lists with free-hand sketches where required were prepared for the use of draftsmen and foremen, and no corresponding articles were made or purchased thereafter where a substitute could be obtained from the collection. All this took much time of officers and employees who were needed elsewhere, and cost a large amount; but it was necessary to overcome the congestion caused primarily by the absence of standard requirements, and the lesson impressed on those who were handling the work was the necessity of standardizing the different items purchased or manufactured.

By inviting a naval constructor to speak on the subject of simplification and standardization it is presumed that the program committee considered that the subject as applied to the work of construction in the Navy would be of general interest to others. This should be so, for in many ways the Navy has either a direct or indirect interest in every phase of the question. We are interested in nearly every material of engineering, for nearly all are used either on warships or in the navy yards and stations. Naval officers regard the question from the viewpoint of designer, manufacturer, storekeeper, distributor, and consumer. All these must be coördinated and directed toward one end, the efficiency of the fleet. In our work on standardization and simplification we act from no selfish motive and we have no ax to grind; our efforts all being directed toward increased efficiency and economy.

THE VARIOUS KINDS OF STANDARDS USED OR USABLE IN SHIPBUILDING

Preliminary to a general discussion let us classify as follows the various kinds of standards which are or may be used in the building of ships:

I—Standardization of Interchangeable Articles Purchased or Made in Quantity. Articles purchased are such as lenses for air ports and dead lights, pipe fittings, hose, galley equipment, hospital equipment, plumbing fixtures, articles of outfit, etc. Articles made in quantity by the shipyard or by the Navy Yard are small boats, doors, manholes, airports, blocks, etc.

II—Standardization of Quality. This type of standardization is exemplified by specifications, such as those for structural steel, rivets, lumber, and practically every other material entering into the completed ship.

III—Standardization of Design and Workmanship. Such standardization is illustrated by type plans of installations, general specifications, and the rules of classification societies and other associations such as the Fire Underwriters. For naval vessels the General Specifications, together with all of the supplements forming part of these specifications, give complete instructions for the workmanship and general design requirements of the entire ship.

Taking up these three classes in order:

[1] Assistant Chief of Bureau of Construction and Repair, Navy Department.

Address delivered on October 26, 1926, at a meeting of the Washington Section of the A.S.M.E. held during Management Week.

STANDARDIZATION OF INTERCHANGEABLE ARTICLES PURCHASED OR MADE IN QUANTITY

Standardization of the type of articles listed in the first class above must be recognized as setting distinct limitations on further progress. When such standards are once set and are widely used it is almost impossible to change them, even though they are later proved to be defective or obsolescent. Before such standards are adopted this disadvantage should be weighed against the obvious advantages of increased economy, convenience in replacement, uniformity of design, etc. A ship is probably less susceptible to standardization of this character than most other products of industry, because the ship is essentially a built rather than a manufactured product. Moreover, many of the articles on a ship falling within this class exist in such limited numbers that they are not carried in stock by any ship chandler. Take, for instance, watertight doors. It is necessary to have numerous types and sizes of these doors to meet the different conditions of access and pressure called for in different parts of ships of different types. Such doors when once made usually last for the life of the ship. The principal expense connected with making these doors is the cost of the materials and the cost of labor. The advantages of universal standardization are quite questionable for an article of this kind, although standards adopted by each great shipbuilding organization, such as the Navy, are found advantageous. Other articles in the first class are more susceptible to standardization. For example, lenses can be standardized in dimensions, the number of different sizes being greatly reduced. Small boats are built in quantities in certain yards, standard working plans for each size being subject to change only in the Navy Department and are modified there only when tried out improvements are added. The number of different sizes is gradually being reduced. Only recently the 35-ft. and 50-ft. motor boats were discontinued, the 40-ft. motor boat being considered sufficient to answer all purposes, and it will gradually replace the others as they disappear. Standardizing the boats means standardizing also the handling and stowage gear and appliances.

The work of standardizing hull fittings and items of equipment is going ahead as rapidly as conservative engineering practice and the availability of competent personnel will permit. A thorough understanding of the limitations is necessary if satisfactory results are to be expected. The work thus far has proceeded along conservative lines and, through the agency of the American Marine Standards Committee, the advantages of the standardization and simplification of ship fittings and equipment are being extended to American merchant ships. Important progress is being made.

STANDARDIZATION OF QUALITY

In regard to the standardization of quality, Class II above, it is essential for a Government establishment such as the Navy to adopt this type of standardization, as the law requires that all purchases made by such an establishment shall be by competitive bidding. Entirely aside from this requirement, however, the standardization of quality of articles purchased is of the greatest benefit both to the user and to the manufacturer. It establishes a uniformity which all manufacturers desiring the business must meet, and therefore makes it difficult for unscrupulous manufacturers to compete successfully by selling goods of inferior quality. Standardizations of this kind should not be considered as permanently fixed. They should be constantly changed to meet the changes in manufacturing procedure and in the requirements of the users. There can be no doubt that standardization of this kind operates to reduce the cost of materials, as well as protect the reputable manufacturers.

This particular phase of standardization has been given special study for a number of years. Some ten years ago this work was put on a going basis by the adoption of standard stocks of certain materials. The standard stock lists prescribe the types, sizes, and quantities which should be carried in stock at various naval stations. It might be remarked in passing that to keep this standard stock list up to date and worth while requires eternal vigilance and means a labor of love on the part of many who are so constituted that they can keep plodding at a job which is of the kind that is never finished. The quality of materials purchased by the Navy is described in Leaflet Specifications, a system of long standing. These leaflets are being worked on constantly to keep them abreast of the times, with due regard for the progress of engineering practice and, of course, the national program of simplification and standardization. They are sometimes criticized as being too severe; but it has been necessary to make them severe to insure getting materials that will stand up under service use. It is well to remember that ships are built to last many years, to stand storm and stress at sea, and even to withstand punishment in battle. The Navy also uses many materials which fall in a different category: materials which well can be of the best regular commercial grade or standard. The Navy is avoiding, wherever practicable, the use of special material and is in favor of the adoption of commercial standards now recognized. As an illustration of progress along this line, we have recently revised one specification for wrenches and have eliminated 49 different types and sizes, a reduction of about 36 per cent. This is simplification and is good business. Also, we have given up our special-dimensioned anchor cables and have adopted and are gradually installing cast-steel chain of commercial dimensions together with the new wildcats required on the anchor windlasses. In this work we often encounter difficulties due to the fact that manufacturers of many materials have no trade standards, even as to size. In other materials we find a multiplicity of standards. There are still others which have passed under the magic wand of standardization, but to no purpose. Unfortunately, there are many standard specifications which have been set up by the trade or by standardization agencies which are not satisfactory from an engineering standpoint and which are not suitable for general use.

An illustration of the difficulties in formulating standard rules is the case of boiler testing in Great Britain, where during the last 30 years three separate committees were appointed by the Institution of Civil Engineers to draft a set of rules. The first one, appointed in 1897, made its report in 1902. The second committee, appointed to bring the first report up to date, ran from 1909 to 1913. Their work did not command the respect of many engineers, who simply ignored it because they considered it impractical. The third committee was appointed in 1924.

Inasmuch as simplification and standardization are not new considerations for the Navy, we are taking active part in the work. We lead as well as follow. Our technical forces are engaged in many problems in connection with the Federal Specifications Board, the American Engineering Standards Committee, the American Society for Testing Materials, the American Marine Standards Committee, and the Division of Simplified Practice. It is hoped that our participation may be increased rather than diminished.

STANDARDIZATION OF DESIGN AND WORKMANSHIP

The art of shipbuilding has probably brought the last type of standardization listed above to a higher state of development than has any other industry. For merchant ships, the requirements of such classification societies as Lloyd's and the American Bureau of Shipping are given in such detail for the various types of vessels that the designer must meet definite design standards in order to secure the classification desired. This type of classification or standardization of types of ships serves principally to protect the underwriter, although it also protects the owner and assists the designer. The rules of the classification societies, although definite, are, in general, not hard and fast; they are subject to change to meet developments in shipbuilding and in ship operating.

Lloyd's dates from 1688 (Hammersley says 1601) and is an association of merchants, shipowners, underwriters, and ship and insurance brokers by whom classes and rates of vessels are established and registered. Lloyd's Register is a list of seagoing vessels of all nations, classified according to seaworthiness by the association, which maintains an inspection of hulls, engines, etc., and supervises British marine construction.

The American Shipmasters' Association was incorporated by the Act of April 22, 1862, in the State of New York, the title being changed to American Bureau of Shipping by order of the Supreme Court of the State of New York in 1898. The constitution adopted in 1922 states that to carry out the object of the charter, it is to "provide classification and registry of mercantile shipping, and to aid and develop the merchant marine of the United States of America."

Corresponding to the rules of classification societies for merchant

ships, we have for naval ships the General Specifications for hull and machinery, together with their supplements. These General Specifications and supplements give complete details as to the design and workmanship requirements for naval vessels, but they permit greater latitude to the designer in developing special types. In fact, the Navy feels itself free at any time to depart from the General Specifications if these specifications are found not applicable to the requirements of new types being designed.

At present in the construction of warships we are standardized in certain characteristics by the terms of the recent Treaty for the Limitation of Naval Armaments. By these terms the maximum displacements and maximum sizes of guns in the main armaments are fixed for battleships, aircraft carriers, and cruisers.

In connection with the question of standard design of merchant ships, it will be remembered that the country was engaged in quantity production of ships during the war. Many ships were built from the same plans; some well built, many poorly built. They were built in record time and accomplished their essential mission. These ships were designed for a definite purpose, and have generally been found unsuitable for peace-time service in competitive commerce in the various lanes of ocean traffic. While they had a large effect in ending the war, and thereby represent a victory in standardization, it must be recognized that this particular application of standard design was successful only for a special set of conditions. This noteworthy instance of standardization teaches us that there are natural limitations which must be studied and not disregarded when we endeavor to undertake standardization in its broadest terms.

A recent transaction is a reminder: In August, 1925, the Government sold to Mr. Henry Ford 199 steel vessels for $1,697,470—a return to the Government of less than one cent on the dollar.

Benefits to Be Derived from Sensible Standardization in Ship Design

The benefits to be derived from sensible standardization in ship design are quite obvious. Standardization stands for economy and facility; economy in time and money; ease of procurement and assurance of suitability for the intended purpose. These advantages are especially emphatic in the case of repair work, as a merchant ship is a financial liability except when it is under way. Interchangeability is an important asset. We want all fire hose to be of the same size and of similar threads so that it will be usable on any ship, and similarly for many other items. Further, interchangeability of personnel in the Navy and in the merchant marine is an important consideration. New personnel on one ship can very readily understand the operation of another ship if standardized equipment and methods are in vogue. This is very important in time of emergency, when the Navy might be called upon to take over and operate many merchant ships. As an example, consider the one item of the marking of pressure piping to designate whether a pipe carries live steam, exhaust steam, salt water, or compressed air. The advantage of similar markings on all ships is entirely obvious. Indeed, there are many avenues for simplification and standardization in ship design. It is highly desirable to standardize where practicable; it is essential to avoid standardizing where impracticable.

It must be well recognized, then, that the program of simplification and standardization is essentially an engineer's job. In undertaking this vast work we must accept responsibility for its outcome. We know it will be a great success of far-reaching betterment if it is worked out on a basis of engineering principles; it cannot succeed if it is worked out on the basis of expediency. For the protection of the reputation of the engineering profession, it is essential that engineers should strive to keep this movement strictly on a firm, conservative, and—above all—technical foundation. The mistakes which are made will be far-reaching and costly. We must guard against mushroom tendencies, superficial studies, and perfunctory action. The setting up of American Standards which cannot be readily accepted by manufacturers and well-informed consumers will be distinctly detrimental, and, of course, worse than no standards at all. I have faith in the work under the guardianship of the Division of Simplified Practice, the American Engineering Standards Committee, the Federal Specifications Board, the International Electro-Technical Committee, the American Marine Standards Committee, and others, but I sometimes feel that there is a tendency on the part of the personnel to rush things unduly in order to "make a showing." If my advice were requested I would say that emphasis should be placed on quality rather than on quantity. Quantity production of American Standards may mean mediocrity and retardment of the work. It is perfectly apparent that "half baked" specifications cannot arbitrarily be set up as American Standards and be expected to stand and enjoy the confidence of consumers and manufacturers. The various standardizing bodies should definitely recognize this fact. Their failure to do so would destroy the country's confidence in them and would surely limit their success if not cause their failure. It is not enough that we go through the paper work of setting up American Standards; a specification which is honored by the designation "American Standard" must stand on a sound technical foundation. Such a foundation is best provided by an unselfish, hardworking, technical committee composed of members who are interested, able, and sincere. The tendency for listless action on the part of such a committee jeopardizes the progress of standardization. It results in the establishment of American Standards which are expedients instead of sound technical specifications. I cannot too forcefully emphasize my sincere hope and feeling that the American Standards which are set up may be worthy of the name. I am fully aware that technical effort on the various committees is voluntary and gratis. It can hardly be expected that the members of the committees can continually work for their regular employers by day and for American Standardization by night. The success of standardization depends entirely upon industrial support, financial as well as moral. If the large commercial concerns will assign to the committee work the requisite number of competent engineers, the movement is bound to succeed, in quantity as well as quality. Without such support, success is questionable. In any event, in adopting American Standards let us maintain the highest standard.

In this connection, we might consider the relation of the Federal Specifications Board to the work of the various standardizing bodies. The question is asked, "Why cannot the Federal Specifications Board adopt and use the specifications which have been promulgated as American Standards instead of duplicating the work by writing other specifications, thus weakening the position of the standardizing societies by withholding Government support?" That important question has been frankly answered somewhat as follows: "U. S. Government Master Specifications are written (and revised when necessary) by as unbiased technical committees as it is practicable to obtain for the purpose of providing adequate specifications for competitive Government purchase of materials; and the business goes to the lowest responsible bidder. Whenever an 'American Standard' definitely provides a material of the grade required, the Government specifications can well be identical to the earlier established standard." In a number of instances standard commercial specifications are accepted. Further progress in this regard would result from increased coöperation between standardizing societies and Government representatives.

The recent war demonstrated that the older methods of warfare must give way to those devised from the results of research, and the President requested the National Academy of Sciences to organize the scientific resources of the country for the national defense. The Academy appointed a committee which later resulted in the organization of the National Research Council of the National Academy of Sciences. After the armistice the President issued an executive order requesting the National Academy of Sciences to perpetuate the research council under its charter on a peace basis. Other governments likewise in the same emergency called to their assistance their scientists and fostered research in the directions necessary to carry on the war. Standardization is akin to research, and could not make much progress without its assistance.

Necessity for Conservatism in the Adoption of Standards

The necessity for conservatism in the adoption of standards is apparent to all who are working on the subject. We do not gain much by issuing a national standard if the manufacturers ignore it, nor if the conditions do not justify it. Consider the situation as regards aircraft at the outbreak of the war: standardization in design was detrimental to progress, but was essential when mass

production had to be introduced to manufacture in large quantities in times of emergency.

During the French Revolution the metric system was evolved and all the world was expected to follow it. The French did not adopt the yard or the pound, but the meter, an imaginary part of the distance from Paris to the north pole, which, incidentally, was incorrectly estimated, and the kilogram, a most impracticable substitute for the pound weight. There was introduced into the United States Senate, July 18, 1921, the following proposed legislation:

> That upon the lapse of ten years from the date of the passage and approval of this act, the weights and measures of the meter-liter-gram, or metric system, shall be a single standard of weights and measures in the United States of America for the uses set out herein.

I am not proposing to argue the case of the metric system, but thought, as it bears so much on our subject, I would give at least some of the advantages and disadvantages. I am informed that not long ago a person interested in the adoption of the metric system questioned American consular offices throughout the world as to the effect on our commerce if America adopted the metric system. There were over a hundred answers received and every one to the effect that the adoption of the metric system would stimulate and increase America's foreign trade. Probably the strongest argument in favor is that the increase in exports alone would compensate for the cost as well as the inconvenience of making the change, and as America's future must depend more and more on our exports to the rest of the world, the strength of that argument must be admitted. The practical arguments advanced as to the ultimate advantages of the metric system are the supposed simplicity and adaptability of the metric measures and the greater ease in making calculations.

Some disadvantages are apparent. Assuming that the intention of the above-quoted law was to cover only the commonly employed units of length (with the derived units of area and volume), mass, and temperature, the arguments against its adoption are the enormous cost and difficulty of transition and the practical impossibility of universal enforcement. It is also claimed by the opponents of the measure that it is only a very slight advantage, if any, that would result to the manufacturers and engineers from the use of the metric system. In the countries where the metric system has been in use for a hundred years or more, the manufacturing standards are by no means universally in this system.

The present units are inseparably connected to the history, the literature, and the standards of manufacture, particularly of shipbuilding, and to the mental concepts of dimensions acquired gradually through life and familiar to all in the shipyard or factory, from the unskilled laborer to the trained engineers, which are fundamental in carrying out work with facility. To change all present standard sizes to conform to metric standards would involve new patterns, rolls, jigs, templets, dies, etc., with corresponding large cost, would not result in exact or simple figures, and would involve confusion in dimensions and in mental conception of sizes. Astronomers and scientists still use the sexagesimal division of the degree and hour into minutes and seconds, notwithstanding the fact that tables for computing in grades and centesimal divisions are in existence, for the reason that their historical records are written in the sexagesimal division, and to change would involve enormous labor considered to be disproportionate to its utilitarian value. Similarly, speeds of seagoing ships are given in knots per hour, even when the dimensions of the ships are given in metric units. Probably the reason for maintaining the established system of sexagesimal division of the degree and hour does not apply so rigidly to the dimensional, mass, or temperature units in the greater portion of scientific work, because previous to the adoption of the metric system there was no uniformity in scientific literature as to these units. In the shipbuilding industry, however, a similar reason exists. The art of naval architecture is largely an empirical one, the success of the design depending largely upon the successful comparison of previously obtained data; therefore the comparative value of different units is an essential part of the work of design, and the judgment of the naval architect, draftsman, designer, business man, purchasing agent, or workman in the new units would be of no value. The valuable files of plans of ships of present and past navies would at once become almost valueless as drawings of precision, as their dimensions would have to be converted, mentally or otherwise, into the new system.

As to the practical arguments in favor which I listed above as simplicity and adaptability and greater ease in making calculations:

In shipbuilding work where the metric system is used there is a constant change in stated dimensions between the millimeter and the centimeter that is apt to be confusing. The units are either too small or too large, and the convenience of the binary subdivision is lacking. The greater number of arguments have been advanced on the advantages of the adaptability of the metric units, with their decimal subdivisions, to calculations; and the practical identity between the kilogram and the weight of a cubic decimeter of distilled water is one of the larger advantages claimed. The shipbuilder, however, has little, if any, use for water of standard density, as his calculations involve salt water of different densities.

Standardization and simplification have for their object increased efficiency by the more economical use of resources, thereby reducing waste, increasing output, and reducing productive costs. Standardization releases energies otherwise wasted in the endless labor over details. Industrial standardization and simplification rendered it possible to produce the automobile at a price which makes it generally available. The necessity for studying standardization in detail and comprehensively is one of the great problems before our industry. It will require all the coöperation, all the knowledge, and all the patience of which human nature is capable to solve this problem, but in the solution is great hope of progress.

In closing, I want to commend the American movement for simplification and standardization. In December, 1921, our Government constituted under the Department of Commerce the Division of Simplified Practice a national campaign toward the elimination of national waste. It makes for economy, facility, and progress. Its influences are widespread; it provides for increased production and distribution of the comforts of life; it leads to better homes and higher standards of living; it is an American ideal worth striving for.

Steel Company Divides Year into Thirteen Periods

THE Lukens Steel Co., Coatesville, Pa., has found after a few months' experiment that a division of the calendar year into 13 equal periods of four weeks each has worked very successfully in arriving at accurate comparisons of operations and costs.

This plan was put into effect last November and the simplification of accounting which it has brought about has convinced the officers of the company that a continuance of the plan is desirable.

Monthly comparisons of operations and costs, when the calendar months were used, did not give the Lukens Company the exact results that were wanted. A month such as February of this year, for example, had four Sundays and two holidays, leaving only 22 working days. January, however, had four Sundays, one holiday, and 26 working days. When a month's expenses were assessed against the output of 22 days the cost of production per ton obviously was higher than in the case of a longer month. The *Iron Age*, vol. 119, no. 10, March 10, 1927, p. 712.

Multiplicity of Patent Claims

CONGRESS at the session just ended passed an act intended to discourage the multiplying of claims in patent papers and a new practice becomes operative April 15. At present there is a flat fee of $20 for filing a patent claim and a second fee of like amount when the patent is issued. Hereafter the minimum fee in either case will be $20, and an additional fee of $1 will be charged for each claim in excess of twenty. Therefore each claim that finally appears in the issued patent in excess of the prescribed number will cost the patentee $2.

Attorneys are hurrying to get long applications filed before the new law becomes effective. Claims already in will not bear the new burden until patents are issued on them. *The Iron Age*, vol. 119, no. 10, March 10, 1927, p. 734.

Temperatures in Powdered-Coal Furnaces Having Extended Radiant-Heat-Absorbing Surfaces[1]

Progress Report of A.S.M.E. Special Research Committee on Boiler-Furnace Refractories

By RALPH A. SHERMAN,[2] PITTSBURGH, PA.

THIS report presents data obtained as a part of the investigation of the proper application of boiler-furnace refractories, being conducted by the Bureau of Mines in coöperation with the Special Research Committee on Boiler-Furnace Refractories of The American Society of Mechanical Engineers.

The data consist principally of temperatures measured in furnaces equipped with extended radiant-heat-absorbing surface and different types of powdered-coal burners. The investigation was conducted at the Sherman Creek Station of the United Electric Light and Power Company, New York City.

It is generally considered that refractories-service conditions are more severe in powdered-coal than in stoker-fired furnaces. If so, this is probably owing to the following factors:

1 Powdered coal can be burned with a low excess of air, resulting in high flame temperatures.

2 All of the ash of the coal is carried in the gas stream, and a larger part may be sprayed on the walls than in a stoker-fired furnace where the greater part of the ash remains on the grate.

3 Temperature changes may be more abrupt on banking, since no mass of incandescent fuel remains in the furnace.

The two principal methods employed to reduce the severity of the refractories service are:

1 Direct cooling of the refractories by passing all or part of the secondary air required for combustion through channels back of the lining.

2 Indirect cooling by supplementing the radiant-heat-absorbing surface of the boiler tubes with side-wall heating surface, water-tube slag screens, and radiant superheaters.

The mean temperature of the gases in a boiler furnace depends upon the following factors:

1 The calorific value of the fuel
2 The rate of combustion
3 The heat capacity of the products of combustion
4 The area of exposed heat-absorbing surface.

The introduction of additional radiant-heat-absorbing surface into a furnace must, other factors remaining constant, lower the mean temperature of the furnace gases. It does not follow, however, that the temperatures of all zones in the furnace decrease to the same extent. The effect of the increased rate of heat absorption on the temperature of a given zone depends upon its position relative to the heat-absorbing surface and the transparency or opacity of the intervening gases.

The temperatures, and consequently refractories service in various parts of a powdered-coal furnace, will vary with different burners, depending upon the position of the burner, the velocity of entrance of the flame, and the methods of air admission.

[1] Published by permission of the Director, U. S. Bureau of Mines.

[2] Assistant Physicist, Pittsburgh Experiment Station, U. S. Bureau of Mines.

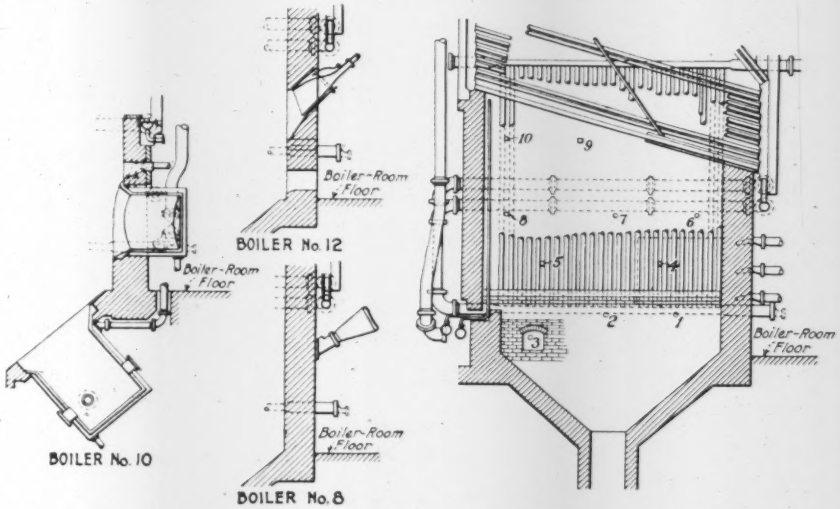

FIG. 1 SECTION OF FURNACE OF BOILER NO. 4, SHOWING POSITIONS FOR MEASURING TEMPERATURES AND ARRANGEMENT OF BURNERS ON FURNACES OF BOILERS NOS. 8, 10, AND 12

OBJECT OF INVESTIGATION

The object of the investigation was to determine the gas temperatures in various parts of the furnaces in order to:

1 Compare the temperature distribution with the several types of pulverized-fuel burners.

2 Compare the temperatures attained in these furnaces with those in furnaces provided with entirely refractory walls.

THE COAL USED

Pocahontas coal was used in all the runs during which the temperatures were measured. A typical analysis of this coal follows:

Proximate	Per cent
Moisture	3.4
Volatile matter	19.6
Fixed carbon	70.6
Ash	6.4
Ultimate	
Hydrogen	4.7
Carbon	81.8
Nitrogen	1.1
Oxygen	5.4
Sulphur	0.6
Calorific value	14,180 B.t.u.

ANALYSIS AND SOFTENING TEMPERATURE OF COAL ASH

A typical analysis of the coal ash showed it to have the following compositions:

	Per cent
Silica	50.9
Alumina	27.7
Ferric oxide	11.2
Calcium oxide	2.7
Magnesium oxide	1.8
Sulphur trioxide	1.9
Sodium and potassium oxides (by difference)	3.8

The determination of the softening temperature of this ash gave the following results:

	Deg. Fahr.
Initial deformation	2180
Softening temperature	2390
Fluid temperature	2470

SCOPE AND METHOD OF INVESTIGATION

The powdered-coal-fired boilers were being subjected to considerable experimentation at the time of these measurements, and, though all steam generated helped to carry the station load, their operation was not regulated by its steam requirements. The measurement of the temperatures given here was carried on as opportunity offered during the combustion and evaporative tests conducted by the test engineers of the station.

Temperatures were measured in four furnaces known at the station as boilers Nos. 4, 8, 10, and 12. The boilers and furnaces were the same in all four, but no two had the same burning equipment. The complete sectional view of Fig. 1 is of boiler No. 4. The three partial views show the locations of the burners in the other boilers. The position of the radiant heating surfaces is indicated in the full view.

TABLE 1 FURNACE-GAS TEMPERATURES, DEG. FAHR.—POWDERED-COAL FURNACES, SHERMAN CREEK STATION

Boiler number	Remarks	Number of burners	B.t.u. per cu. ft. per hr.	CO_2 in flue gas	Position 1	2	3	4	5	6	7	8	9	10
10		1-Lower	12,625	14.6	1736	2049	2123	..	..	..	..	1712	1502	1584
		1-Lower	12,625	14.0	1750	2000	2123	..	..	..	..	1856	1808	1567
		2-Upper	16,985	14.7	2449	1780	1920	..	..	..	..	1832	1900	1776
		2-Upper round and lower	20,130	14.0	2327	2241	2261	..	..	..	..	1920	1936	1904
		2-Upper round and lower	20,130	14.4	2422	2247	2323	..	..	..	..	2093	1967	1888
12		4	11,175	13.6	2518	2308	2292	2031	2354	..	..	2159	1904	1999
		4	11,175	13.8	2459	2323	2184	2062	2308	..	..	..	..	..
		4	15,365	13.4	2693	2577	2547	2400	2385	..	..	..	..	2123
		4	15,365	14.4	2679	2562	2547	2370	2444	..	..	..	..	2169
		4	22,500	12.1	2793	2636	2693	2533	2533	..	..	..	..	..
4	Side-wall tubes exposed	6	14,175	14.4	2150	2477	2459	..	..	1805	1684	2077	1698	1872
		9	25,680	14.6	..	..	2400	..	..	2273	2189	2414	2049	2154
4	47 sq. ft. of side-wall tubes bricked over	6	13,825	13.5	2025	2270	1950	..	..	1698	1725	1886	1584	1712
		6	13,825	13.9	2107	2258	1975	..	..	1766	1766	2000	1628	1807
		9	26,335	13.2	..	2477	..	..	..	2235	2224	2305	2025	2096
		9	26,335	13.2	2606	2606	2292	..	..	..	2261	2429	1983	2123
4	All of side-wall tubes bricked over	6	12,000	14.9	2200	2230	2060	..	..	2207	2246	2323	2131	2139
		6	12,000	14.8	2062	2323	2108	..	..	2230	2215	2093	2093	2007
		9	24,150	14.3	2215	2518	2261	..	..	2562	2547	2215	2400	2488
		9	24,150	14.4	2308	2230	2354	..	..	2547	2215	2093	2414	2459
8		2	15,190	15.4	..	1832	1623	2219	1873	..	..	..	..	..
		2	23,674	16.7	..	2800	2665	2164	2611	..	..	..	..	..

The boilers had the following characteristics:

Combustion space	3060 cu. ft.[1]
Boiler heating surface	6280 sq. ft.
Side-wall fin tubes:	
Total heating surface	432 sq. ft.
Projected area exposed to radiation	198 sq. ft.
Radiant superheater	235 sq. ft.

[1] Boiler No. 10 had 230 cu. ft. combustion space and 140 sq. ft. of heating surface additional in its three burner boxes.

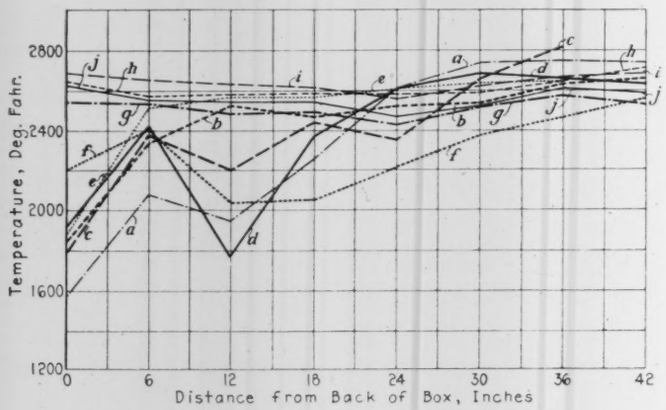

FIG. 2 TEMPERATURES IN BURNER BOXES, BOILER NO. 10

Curve	Box	B.t.u. per cu. ft. per hr.	CO_2 per cent
a	Upper round	16,985	14.7
b	Upper square	16,985	14.7
c	Upper round	20,130	15.6
d	Upper round	20,130	15.6
e	Upper round	24,980	17.2
f	Upper square	24,980	17.2
g	Lower	13,400	15.5
h	Lower	13,400	16.5
i	Lower	17,644	..
j	Lower	21,375	16.5

Temperatures were measured by means of a platinum, platinum-rhodium thermocouple and potentiometer at five to eight positions between the side wall and central vertical plane of the furnace at part or all of the positions, 1 to 10, shown in Fig. 1. From 20 to 50 observations were taken in each furnace at each rate of firing. It is shown later in the report that the temperatures did not vary greatly across the furnace at any position. Therefore the temperatures at 4 ft. from the side wall were selected to show the typical temperature distribution in the furnaces. Table 1 gives these temperatures.

DISCUSSION OF RESULTS

Boiler No. 10. The furnace of this boiler was equipped with "well-type" burners. These "wells" consisted of round or square boxes, open on the furnace side, into which the powdered coal, together with all the air necessary for its combustion, was fed through four round pipes set in the sides of the box slightly off center lines or diameters so as to produce a vortex effect. The coal was supplied from a central pulverizing mill and bin.

Three burner boxes were fitted to this furnace, one square box on the front hearth below the boiler-room floor line, and two smaller boxes, one round and one square, on the front wall above the floor line. They were built of boiler plate with a second outer box forming a shell through which water flowed, cooling the inner plate.

Fig. 2 shows the temperatures measured in these burner boxes at intervals of 6 in. from the back toward the furnace opening.

The back and bottom of the lower box had a $2^1/_2$-in. firebrick lining at the time the temperatures were measured. This probably accounts for the higher temperature just inside this box than in the two smaller boxes. The temperatures were generally low in the latter at 12 in. from the back, which coincides with the plane of the coal stream. The temperature range at 42 in., which, in the small boxes, was the plane of entrance of the gases into the furnace, was about 200 deg. fahr. (2500 to 2700 deg.), varying little with the rate of combustion.

Reference to Table 1 shows that no temperature measured in the furnace proper of this boiler was greater than 2450 deg. fahr. This indicates that after entering the furnace the gases were losing heat faster than it was being released by combustion.

Position 3, near the rear hearth, was the critical one as regards refractories in these furnaces since, owing to the change in the direction of the gases here, a large part of the ash was thrown out on this part of the refractory lining. The highest temperature read here was but slightly over 2300 deg.

The temperatures just below the boiler tubes, positions 9 and 10, varied from approximately 1500 to 2000 deg., increasing with the rate of firing. The variation of the temperature with the rating in the lower part of the furnace was obscured by changes in the burners used, which caused the gases to flow in different streams.

Boiler No. 12. This boiler was equipped with four burners of the flat, fishtail type which were arranged in two pairs, each pair being supplied from its own pulverizing unit with the powdered coal and 15 to 20 per cent of the air necessary for combustion. The remainder of the air entered through ports in the front wall.

The flame on leaving the burner did not spread upward at once but continued sharply downward toward the rear hearth. This is indicated by the fact that the temperatures at positions 1 and 2 are higher than those at position 4. The highest temperature (approximately 2800 deg.) was at position 1 at a rate of combustion of 22,500 B.t.u. per hour.

The temperature difference between positions 1 and 3 decreased from 200 to 250 deg. at the lowest rating to 100 deg. at the highest rating. The limit of zone of maximum intensity of combustion was moved well to the rear of the furnace at the high ratings.

Boiler No. 4. This boiler was equipped with nine burners of the flat type, their largest dimension horizontal. The burners were curved downward to direct the flame toward the bottom of the furnace. Coal was supplied from the central pulverizer and bin. Temperature readings were taken in this furnace under three conditions:

1 With all the side-wall tubes exposed.
2 With 47 sq. ft. (indicated by dash lines just in front of the burners in Fig. 1) covered with 9 in. of firebrick.
3 With the entire side-wall heating surface covered with 9 in. of firebrick.

There were no marked differences between the temperatures when a portion of the side-wall surface was covered and when all

was exposed. The temperatures on the lower-plane positions 1, 2, and 3 were apparently higher with the latter condition, but the limited number of observations render the value of close comparisons doubtful. However, since the surface covered was less than one-fourth of the total, the differences would not be expected to be large.

The temperatures on the lower plane were not greatly different when all the side-wall heating surface was covered, but those at positions 6, 9, and 10 increased. The temperature range of the gases entering the boiler tubes when the tubes were partly covered was from 1600 to 2100 deg., while with the tubes entirely covered the range was from 2100 to 2450 deg. A part of this difference may have been owing to the higher CO_2 in the flue gas in the latter case, though this was offset to some extent by the lower rates of combustion.

Boiler No. 8. This boiler was equipped with two oblong burners, their longest dimension horizontal, through which the coal from the central bin, plus all the air for combustion, was supplied. Temperature observations were taken in this furnace at two rates of combustion only.

The temperatures in the lower part of the furnace at the

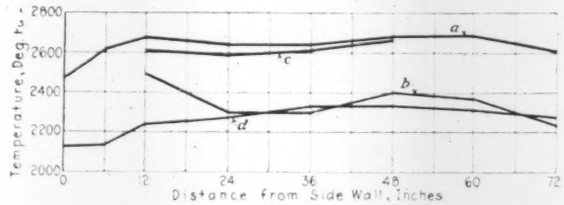

FIG. 3 TEMPERATURE VARIATIONS ACROSS FURNACE AT POSITION 3

Curve	Boiler No.	Rate of combustion, B.t.u. per cu. ft. per hr.
a	12	22,500
b	4	25,080
c	8	23,674
d	10	20,130

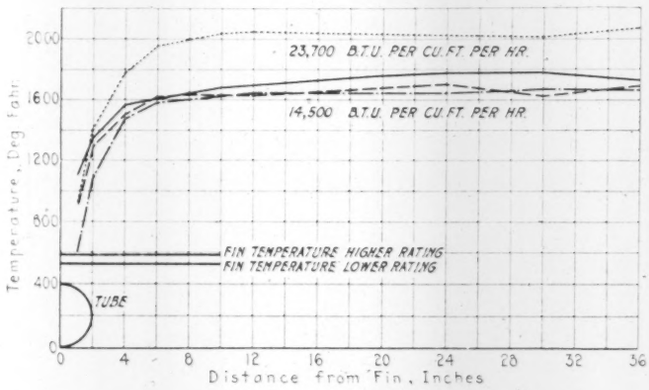

FIG. 4 VARIATION OF GAS TEMPERATURE FROM SIDE-WALL TUBE FINS

lower rating were comparatively low but at the higher rating reached 2800 deg. at position 2 and 2665 deg. at position 3.

The furnace was operated during these observations under such conditions as to cause slagging of the ash. The coal burned had a softening temperature of 2240 deg. and a fluid temperature of 2450 deg., somewhat lower than normal for the station coal.

The temperature of the gases near the back of the furnace at the higher rating, as was pointed out, was well above the fluid temperature of the ash, and the ash deposited on the hearth ran from the ash outlet in a viscous slag. The temperatures at the lower rating were too low to slag the ash and removal as a slag was impossible.

VARIATION OF GAS TEMPERATURE ACROSS FURNACE

Fig. 3 shows the variation of the gas temperatures in the furnace of the four boilers at position 3 for similar rates of combustion. The temperatures were generally quite uniform across the furnace, excepting those just inside the wall which were low.

Fig. 4 shows the variation of the gas temperatures at short intervals away from the fin tubes for two rates of combustion in Boiler No. 10. These observations were taken at position 8. The temperatures of a fin, measured 1 in. from the tube on the side away from the fire, are also shown. The temperature curves were quite flat after 6 in. from the fins or 4 in. from the outside of the tubes.

REFRACTORIES TEMPERATURES

Fig. 5 shows temperature gradients through a brick in the lining on the back of the lower burner box of Boiler No. 10. The bricks were laid flat on the metal lining and the thermocouples were placed $1/2$, $1\,1/4$, and 2 in. from the hot face. The temperatures were

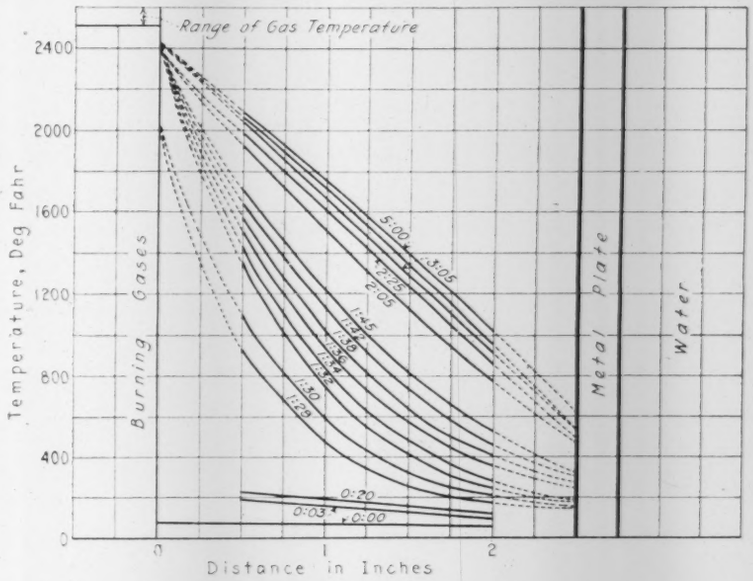

FIG. 5 TEMPERATURE GRADIENT THROUGH BRICK IN LOWER BOX

extrapolated to the surface as shown by the dotted lines. The figures on the curves give the time in hours and minutes from the lighting of the burner.

Equilibrium was established, indicated by the straight line, at about three hours from the time of firing. The temperature of the hot face slightly exceeded 2400 deg., while the gas temperature within the box at the face lay between 2500 and 2600 deg. The temperature on the cold face was 600 deg. The exact water temperature is unknown. The water entered at about 32 deg. and left at not over 140 deg.

The temperature gradient through the bricks was about 750 deg. per inch. Therefore the temperature $1/4$ in. from the hot face was below the softening temperature of the ash. During the period this lining was under observation no serious erosion had taken place, but the actual service was too limited to draw definite conclusions.

Temperatures were measured in bricks placed in the side wall of Boiler No. 4 with the tubes partly and entirely bricked over. Fig. 6 shows the temperature gradients through a brick near position 2, Fig. 1, which was a 9-in. header in a $13\,1/2$-in. wall. The thermocouples were located at distances of 1, 3, 6, and 8 in. from the hot face of the brick. The figures on the curves refer to the time in hours and minutes from lighting burners.

A drying fire had been lighted in the furnace the previous evening for two hours, which accounts for the temperature of the brick at the start being about 200 deg. More heat was entering the brick than leaving it, even 8 hours after lighting the burners, as shown by the upward concavity of the curves. The maximum temperature of the surface at this boiler rating, 150 per cent, was about 2200 deg.

Fig. 7 shows the temperature gradients through this same brick with the tubes partly and entirely bricked over. These boilers were operated, as previously stated, for testing purposes only, and the heat flow through the brickwork did not always reach an equilibrium condition in the duration of a test. This probably accounts for the difference in the slopes of the curves. For this reason the apparently large difference at 150 per cent of rating between the temperature when the side-wall tubes were partly and entirely bricked over and the much smaller difference at 270 per cent may not represent the true effect of the decreased radiant heating surface.

The effect of the decrease in the area of radiant heating surface was, however, somewhat more clearly marked on the brickwork temperature than on the gas temperatures in this part of the furnace.

Fig. 8 shows the temperature gradients in this brick at different boiler ratings when the side-wall heating surface was entirely covered. The same remarks about equilibrium conditions in the heat flow apply for this as for the preceding figure. The maximum temperature reached at the surface at 270 per cent of rating was 2650 deg. The ash was, of course, molten at this temperature, but it was still so viscous that no serious erosion took place.

Refractories Service

The period of operation of these boilers was too limited to determine the probable length of life of the refractories under the various conditions of service. Observations on the condition of the ash deposited in the furnace during the operation, however, permit some predictions as to the probable service.

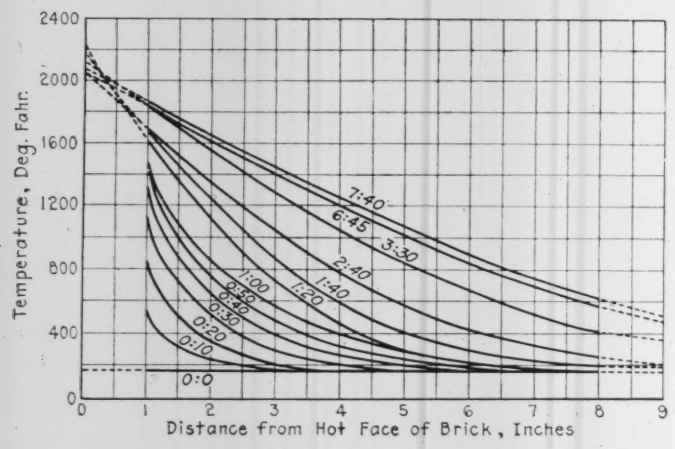

FIG. 6 TEMPERATURE GRADIENT THROUGH BRICK IN SIDE WALL AFTER LIGHTING BURNERS

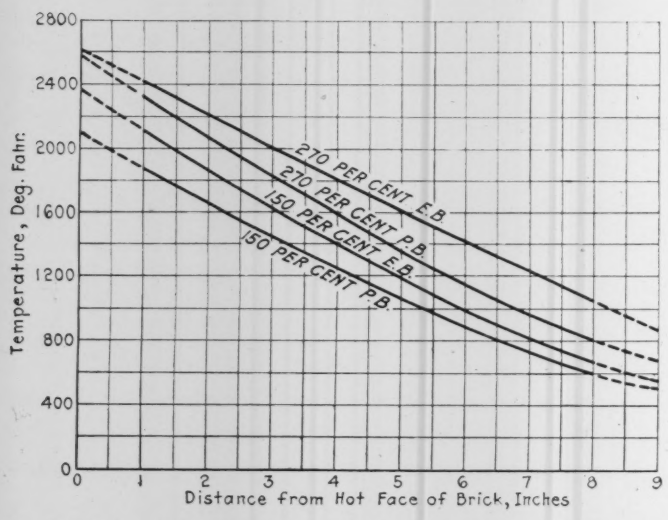

FIG. 7 TEMPERATURE GRADIENT THROUGH BRICK IN SIDE WALL WITH TUBES PARTLY (P.B.) AND ENTIRELY (E.B.) BRICKED OVER

The ash was deposited in Boiler No. 10 in a granular condition, and there was little difficulty in removing the ash from the furnace. Similar conditions obtained in Boiler No. 4. The ash which did melt on the walls formed a viscous slag, which apparently only slightly eroded the refractories.

It has been stated in regard to Boiler No. 8 that it was operated at the time the temperature readings were taken under conditions favorable to produce slagging of the ash. Since the ash was deposited on the hearth in a molten state and flowed out of the furnace in this state, it is probable that it fluxed and removed with it considerable refractory.

Little trouble was experienced with slagging of the ash in Boiler No. 12 at the lowest ratings, but at higher ratings the ash was deposited on the walls and hearth as a slag. It will have been noted in Table 1 that at the rate of combustion of 22,500 B.t.u. per cu. ft. per hr. the CO_2 in the flue gas was but 12.1 per cent. It was necessary to increase the excess air to this extent to avoid closing up the ash outlet with slag.

General Summary of Results

Kreisinger and Blizard[3] in the report of the Oneida Street, Milwaukee, tests present the results of a survey of the gas temperatures in a small powdered-coal furnace having 4680 sq. ft. of heating surface and 76.5 sq. ft. of projected area of boiler tubes. This furnace did not have side-wall heating surface or radiant superheaters, but did have a water-tube slag screen with a projected area of 17 sq. ft. The maximum temperature was found just above this screen, and at a rate of combustion of about 21,000 B.t.u. per cu. ft. per hr. and 15 per cent CO_2 the temperature was 2700 deg.

In Boiler No. 12 at the Sherman Creek Station, with similar burners and a projected area of boiler tubes of 135 sq. ft., of side-wall heating surface of 198 sq. ft., and of radiant superheater of 235 sq. ft., the maximum temperature at 22,500 B.t.u. per cu. ft. and 12.1 per cent CO_2 was approximately 2800 deg. The maximum temperature was higher in the Sherman Creek test, although the area of the radiant heating surface in that furnace was six times that in the other. The zone of maximum intensity of combustion was located similarly in the two furnaces, that is, near the bottom. It is probable that had there been no water-tube slag screen in the Oneida Street furnace the maximum temperature would have been higher as the screen was in a position to receive the direct radiation from this zone.

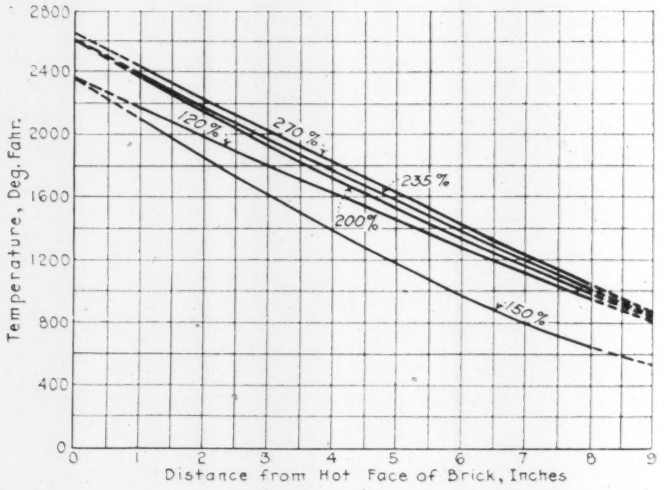

FIG. 8 TEMPERATURE GRADIENT THROUGH BRICK IN SIDE WALL AT VARIOUS RATINGS

Temperatures of 2700 and 2800 deg. were found in the other furnaces at the Sherman Creek Station. These experimental data bear out the statement made in the opening discussion that although the mean temperature of the furnace must decrease with an increase in radiant-heat-absorbing surface, it does not necessarily follow that the temperatures in all parts of the furnace decrease. The zone of maximum intensity of combustion in Boiler No. 12 was not in proximity to the heat-absorbing surface. Hence the temperatures were high and the slagging severe. Had the heat-absorbing surface been placed in this part of the furnace the temperature would have been lowered and the severity of slagging lessened.

Boiler No. 10 furnished an example of the elimination of slagging difficulty by keeping the zone of maximum intensity of combustion and heat-absorbing surface together. Although the combustion within the burner boxes was very rapid, the temperature was kept down by the heat transfer to the cooling water in the boxes. When the gases left the boxes they were receiving less heat by combustion than they were losing by radiation, and hence were so cooled when they reached the back wall that there was little slagging.

[3] Kreisinger, Henry; Blizard, John; Agustine, C. E.; and Cross, B. J.: An Investigation of Powdered Coal as Fuel for Power-Plant Boilers. Bureau of Mines Bulletin No. 223, 1923, p. 67.

Rough Turning with Particular Reference to the Steel Cut[1]

By H. J. FRENCH[2] and T. G. DIGGES,[3] WASHINGTON, D. C.

Tests described in this report extend to current commercial high-speed tool and structural alloy steels portions of Taylor's original investigations in rough turning carbon steels. They were made primarily to show the effect upon tool performance of variation in chemical composition and mechanical properties of the steel cut, and accordingly include lathe tests on carbon, nickel, low- and high-chromium, chromium-vanadium, chromium-molybdenum, and nickel-chromium steels having tensile strengths between 65,000 and 195,000 lb. per sq. in. However, many of the tests with the customary high-tungsten–low-vanadium steel tools were duplicated with low-tungsten–high-vanadium or cobalt high-speed steel tools, and there is included a partial study of the effects of cutting speed, feed, depth of cut, and coolants upon tool life and the power required in cutting. Graphical representation of results is employed, wherever possible, to show the laws of cutting.

DURING the past several years the authors have studied so-called "lathe-breakdown" and "Taylor" (1)[4] tests and the effects of certain major changes in chemical composition and heat treatment upon lathe-tool performance, dimensional changes, and other characteristics of commercial high-speed steels (2, 3). In general, the tools were tested "dry" at fixed feed and depth of cut on 3 to 4 per cent nickel-steel forgings heat-treated to show tensile strengths in the neighborhood of 100,000 lb. per sq. in.

The tests to be described were made on carbon and various alloy steels having definite tensile strengths within the range 65,000 to 195,000 lb. per sq. in. (approximately 130 to 400 Brinell hardness). The investigation was primarily a study of tool performance as affected by the conditions of cutting (variations in material cut, cutting speed, feed, and depth of cut); the form of the tool and its heat treatment were not varied. However, many of the tests with the customary high-tungsten–low-vanadium high-speed steels were repeated with other commercial types, thus permitting comparisons under variable cutting conditions.

MATERIALS AND METHODS EMPLOYED

The Tools

The original plans for the investigation consisted mainly of a study of tool performance in cutting $3\frac{1}{2}$ per cent nickel, nickel-chromium, chromium-molybdenum, and some carbon-steel forgings having tensile strengths between about 80,000 and 150,000 lb. per sq. in. Subsequently the investigations were extended to include tests on steels of higher hardnesses and other types, such as the carbon-chromium, chromium-vanadium, and other nickel-chromium steels.

The chemical compositions and heat treatments of the high-speed-steel tools used are reported in detail in Table 1. The equipment and procedure employed in all phases of preparation of the tools and in carrying out the lathe tests was similar to that described in a previous report (2). All tools had a cross-section in the body of $\frac{1}{2}$ in. by $\frac{1}{4}$ in., and when first prepared were about $4\frac{1}{2}$ in. long; some were hot-finished to the desired size, while others were cut from larger bars, either $\frac{7}{8}$ in. or 1 in. by $1\frac{1}{2}$ in. In such cases care was taken to grind the top of the tool near the surface of the hot-finished bars to avoid introducing variables from segregation and porosity. The tool form was the same as in tests previously reported and consisted of front and side clearances of 6 deg., side slope of 14 deg., back slope of 8 deg. and a nose radius of $\frac{1}{8}$ in.; it was not varied throughout the investigations. Except in special cases where effects of coolants were studied, the tools were run dry. Cutting speed, feed, and depth of cut were varied, depending upon the purpose of each set of tests. A photograph of the test lathe and tool holder is reproduced in Fig. 1.

The "Logs" and Test Methods

The "logs" upon which the cuts were taken varied from about 2 to 14 in. in diameter and from 2 to 6 ft. in length. The largest and solid forgings were used for the development of low tensile strengths or in cases in which a high tempering temperature could be used subsequent to hardening. Hollow-bored forgings were prepared when high tensile strengths were desired, but despite

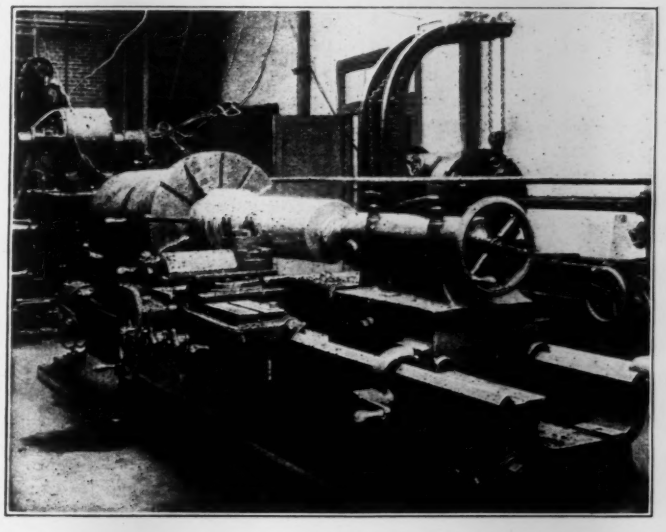

Fig. 1 Type of Lathe and Tool Holder Used in Tool Tests

the increase in speed of cooling and an increase in depth of hardening obtained by removing metal at the axis of large rounds prior to heat treatment, it was not possible to secure the highest tensile-strength values or reasonable uniformity in physical properties with certain of the steels. In such cases the lathe tests were made on small rounds, about 2 to 4 in. in diameter and 3 ft. long. The difficulties mentioned were largely restricted to the chromium-vanadium and carbon-chromium steels heat-treated to show tensile strengths around 150,000 to 175,000 lb. per sq. in. An additional precaution was taken to secure representative results by carrying out tests in "sequence." For example, in comparing the performance of high-tungsten–low-vanadium and high-tungsten–cobalt steel tools, a test was first made with one type, then the other. The average tool life was referred to the average properties of the test log as determined upon specimens cut from metal at the starting and finishing diameters of the cutting tests. Metal was also removed from the surface of the forgings to eliminate scale and the large hardness gradients usually found next to the surface when large sections are quenched and tempered to show high hardnesses.

EXPERIMENTAL RESULTS

Relation Between Cutting Speed and Tool Life in Dry Rough Turning

Taylor (4) found that the change in life of a high-speed-steel tool with changing cutting speed could be represented approximately by an empirical equation:

$$VT^n = c \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [1]$$

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[1] Published by permission of the Director of the Bureau of Standards.

[2] Senior Metallurgist, Bureau of Standards.

[3] Assistant Scientist, Bureau of Standards.

[4] The numbered references in parentheses refer to the bibliography appended to this report.

Contributed by Machine Shop Practice Division and the Research Sub-Committee on Cutting and Forming of Metals, and presented at the Annual Meeting, New York, December 6 to 9, 1926, of The American Society of Mechanical Engineers. Abridged.

in which V = cutting speed in feet per minute
T = tool life in minutes
c = a constant which is dependent for its numerical value upon the exact cutting conditions (other than speed). It will vary with the form and size of tools, material cut, steel (and treatments) from which the tools are prepared, feed, and depth of cut.

Working with carbon steels having a tensile strength in the neighborhood of 70,000 lb. per sq. in. and with tools of definite size and shape made from steel containing about 1.9 per cent carbon, 8.5 per cent tungsten, and 2 per cent chromium, Taylor found $n = 1/8$ and

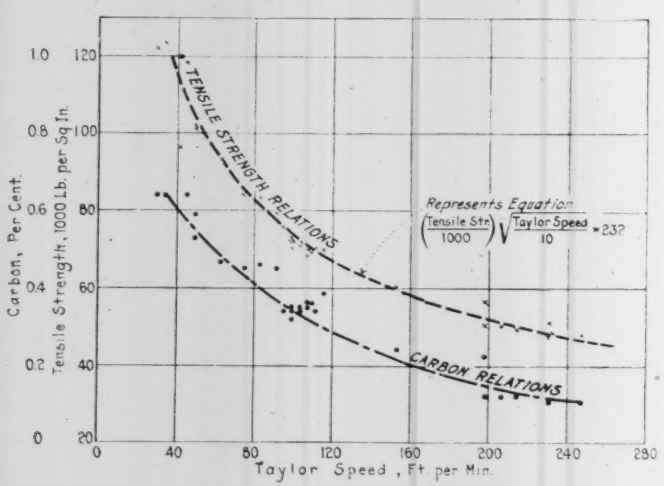
Carbon, Per Cent.
Tensile Strength, 1000 Lb. per Sq In.
Taylor Speed, Ft per Min.
TENSILE STRENGTH RELATIONS
CARBON RELATIONS
Represents Equation
(Tensile Str/1000) √(Taylor Speed/10) = 232

FIG. 2 SUMMARY OF TAYLOR'S LATHE TESTS SHOWING EFFECT OF CARBON CONTENT AND TENSILE STRENGTH ON CUTTING SPEED OF ANNEALED OR HOT-WORKED CARBON-STEEL FORGINGS

(Tests made dry with 7/8-in. tools containing 0.68 C, 5.75 Cr, 18.0 W, 0.3 V, a 3/16-in. depth, and 1/16-in. feed.)

for all computations involving the relations between cutting speed and tool life. The question whether this value of n would fit best a wider range of conditions is not important. The tool lives observed in the main body of the investigation ranged between 2 and 20 min. The difference in computed Taylor speeds from any of these observations caused by a change from $n = 1/7$ (the value adopted) to $n = 1/8$ (Taylor's original value) would in no case be greater than 5 per cent, which is within the limits of reproducibility of results.

MACHINABILITY OF CARBON AND SPECIAL STEELS FROM THE STANDPOINT OF LATHE ROUGHING TOOLS

This subject is a very large one, and it may be well to emphasize at this point the fact that the experiments to be described are restricted to a type of machining commonly referred to as "hogging" or rough turning.

The terms "machinability" and "machining qualities" have been loosely employed to indicate the finish produced on the work, the power required in removing metal, and in some cases the speed with which machine tools may be operated or the length of time before tools must be dressed or reground, etc. However, the primary object in rough turning is to remove the maximum amount of metal in minimum time at the least cost. Under such conditions the most important factor is tool life, and steels which, under otherwise fixed conditions, permit the longest cuts without regrinding of the tools may be said to be the most readily machinable. It is on the basis that "machinability" is proportional to tool life that this term is used in subsequent sections of this report.

Taylor (4) pointed out that "the physical properties of steel constitute a fairly accurate guide to its cutting speed," but also states that "no absolute and accurate relation exists between the cutting speeds of forgings whose chemical and even physical properties very closely agree." Despite this very definite statement, it appears to be common practice to use Brinell hardness as a criterion of cutting qualities. While justified under certain conditions, such relations are at best only a general indication, and many exceptions can be cited even for a restricted class of metals.

TABLE 1 CHEMICAL COMPOSITIONS AND HEAT TREATMENTS OF THE LATHE TOOLS USED IN THE INVESTIGATION

Steel No.	Chemical composition, per cent C	Mn	P	S	Si	Cr	W	V	Co	Ni	Mo	Annealing [b] Temp., deg. fahr.	Annealing [b] Time, hr.	Pre-heating for hardening	High-heat [c] Temp., deg. fahr.	High-heat [c] Time, min.	Tempering
HIGH-TUNGSTEN–LOW-VANADIUM																	
E	0.62	0.32	0.020	0.014	0.32	3.94	17.86	0.68	....	0.14	....	1600	3	1600 deg. fahr., 20 minutes	2400	1½	1100 deg. fahr., 30 minutes and cooled in air
I	0.63	0.29	0.012	0.024	0.25	3.97	18.88	0.81	....	0.15	....	1600	3	"	2400	1½	"
M[a]	0.69	0.29	0.025	0.022	0.24	3.78	18.12	1.14	....	....	....	....	..	"	2400	1½	"
N[a]	0.70	0.29	0.034	0.015	0.24	3.74	18.68	1.15	....	....	....	....	..	"	2400	1½	"
D	0.64	0.39	0.017	0.017	0.06	3.93	18.33	0.85	....	....	....	1600	3	"	2400	1½	"
LOW-TUNGSTEN–HIGH-VANADIUM																	
H	0.66	0.32	0.029	0.025	0.42	2.99	12.67	1.74	....	0.18	....	1600	2	"	2350	1½	"
L	0.71	0.31	0.029	0.026	0.24	3.60	12.75	1.99	....	....	....	1600	3	"	2350	1½	"
C	0.68	0.42	0.022	0.013	0.16	4.37	13.91	1.64	0.09	0.12	....	1600	2	"	2350	1½	"
HIGH-TUNGSTEN–COBALT																	
G	0.59	0.41	0.021	0.008	0.15	3.25	18.51	1.17	3.45	....	....	1600	3	"	2450	1½	"
K	0.60	0.12	0.008	0.026	0.12	2.95	18.23	.99	3.50	0.09	....	1600	3	"	2450	1½	"
P[a]	0.70	0.30	0.028	trace	0.36	3.90	17.92	1.08	4.83	....	0.41	1600	3	"	2450	1½	"
B	0.68	0.42	0.013	0.016	0.15	3.67	17.97	.73	3.06	0.04	....	1600	3	"	2450	1½	"

[a] Manufacturer's analysis.
[b] Tools were pack-annealed in a mixture of dry sand plus 10 per cent wood charcoal.
[c] All tools were quenched in a proprietary quenching oil.

$c = 90$. In tests reported by the Lathe Tools Research Committee (5), the numerical value of the constant c varied between about 120 and 150, but the law originally developed by Taylor was confirmed for durations of cut between about 3 and 100 min. under conditions differing widely from those of Taylor's experiments. However, not all investigators [See references (5) and (6)] have confirmed Taylor's value of the exponent. The value $1/7$ fits more closely some of the results previously published by the authors (2). Additional tests were run with the same shape of tool and same feed and depth of cut. The tests cover in all four different types of high-speed steel, cutting steels differing either in heat treatment or chemical composition.

The results given in Table 4 all agree sufficiently closely with $n = 1/7$. It was decided, therefore, to use the equation

$$VT^{1/7} = c \quad \ldots\ldots\ldots\ldots\ldots\ldots [2]$$

Allcut and Miller (7) give a tabular comparison of Brinell hardness, tensile strength, and approximate cutting properties of carbon and alloy steels, based upon general observations in commercial machining and expressed as a proportion of the cutting properties of 0.20 to 0.25 per cent carbon steel having a tensile strength of about 56,000 lb. per sq. in. (25 tons per sq. in.) which has been given a value of 100 for turning with a single-point tool. The limit of commercial machining is stated to be about 30, which corresponds approximately to a Brinell hardness of 207 for drilling and 225 to 250 for turning, planing, and milling. These values are exceedingly low for some types of cutting and quite different from limits found in commercial practice in the United States.

The comparisons of Allcut and Miller show that large increases in Brinell hardness adversely affect the machining properties of

steels, but in other respects they are liable to be misleading, for Brinell hardness is no certain criterion of the behavior of steels in machining. As an example, Kessner (8) shows that even in one type of metal there is no quantitative relation between drill penetration and Brinell hardness or ball indentation tests. Emmons (9) has discussed the structure of carbon tool steels in relation to different cutting and forming operations, and shown that the best structures for one type of cutting are not necessarily the best for others.

Haughton (10) states that of the "high-tensile steels," that with 3 per cent chromium machines better than the nickel-chromium structural steels, and much better than the customary nickel steels of equal hardness.

Of late considerable emphasis has been placed upon the desirable machining qualities of the structural alloy steels containing molybdenum in comparison with nickel-chromium and $3^1/_2$ per cent nickel steels when heat-treated to show comparable tensile strength or hardness, but little has been published to substantiate the superiority claimed. Pierce (11) claims an increase in production for certain operations amounting to about 10 to 25 per cent when the nickel-chromium steel being machined was replaced by chromium-molybdenum steels of the customary commercial types.

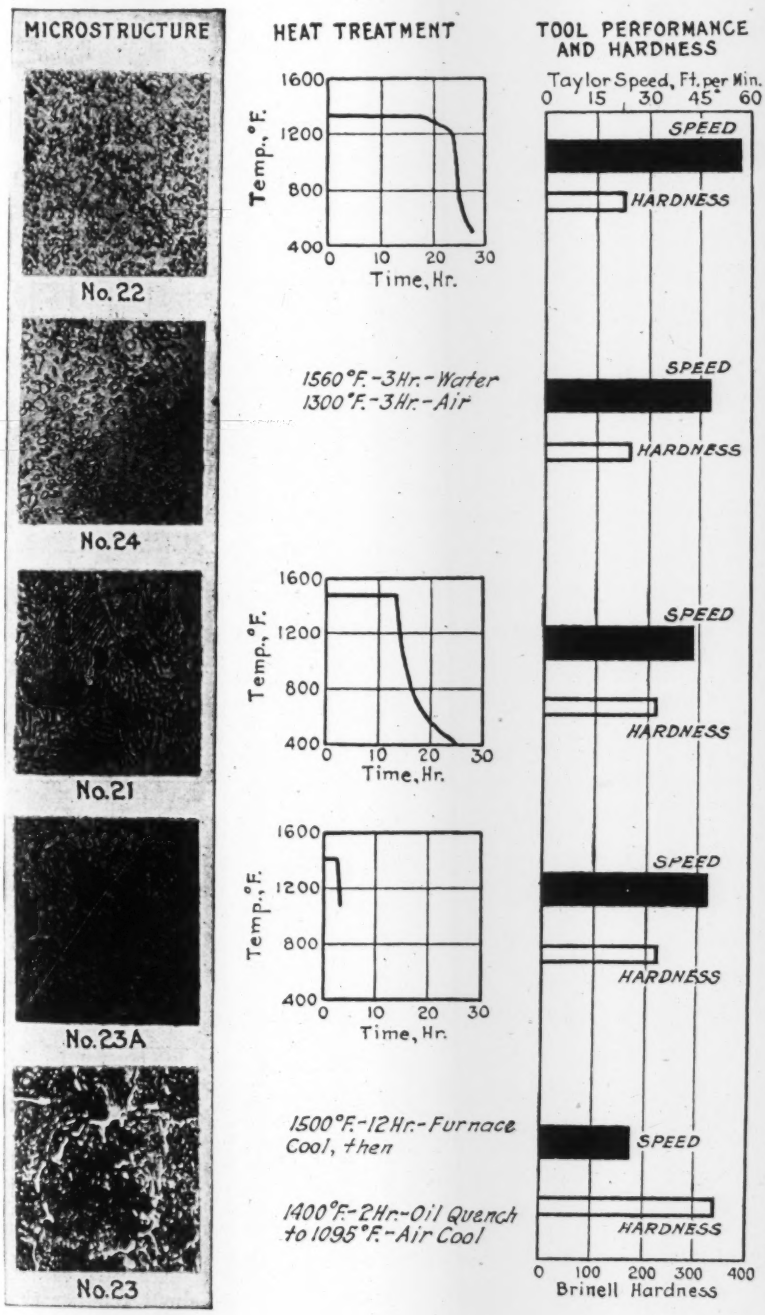

FIG. 3 CORRELATION OF LATHE-TOOL PERFORMANCE WITH HEAT TREATMENT, BRINELL HARDNESS, AND MICROSTRUCTURE OF A 1.05 PER CENT CARBON STEEL

(Lathe tests were made with high-speed steel I (Table 1) and tools of form described in text, run dry with a depth of cut of $^3/_{16}$ in. and a feed of 0.028 in. The photomicrographs are at a magnification of 500 diameters. Samples etched with 2 per cent nitric acid in alcohol.)

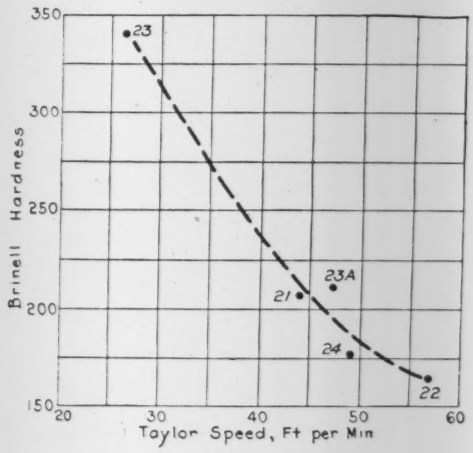

FIG. 4 RELATION BETWEEN CUTTING SPEED AND BRINELL HARDNESS OF 1.05 PER CENT CARBON STEEL

(Based on data included in Fig. 3.)

These reports refer in most cases to types of cutting quite different from that associated with the original development of high-speed cutting tools. Likewise they deal largely with the machining of particular types of steel or to comparisons of a few steels within narrow ranges of hardness. They do not all contain sufficient detail to permit a check on the conclusions, and so are not always convincing.

CARBON STEELS

No new tests were made to show the effect of carbon upon the cutting speeds of annealed or hot-finished carbon-steel forgings, as this subject formed the basis of many of Taylor's experiments. His results, reproduced in part in Fig. 2, show that the cutting speeds vary for different forgings whose chemical and physical properties very closely agree, but that appreciable increases in carbon tend to reduce the cutting speeds.

Taylor did not so fully follow the effects of variations in annealing practice, particularly with respect to the cutting of high-carbon or so-called hypereutectoid steels, and therefore this subject was the basis of a set of experiments which are summarized graphically in Figs. 3 and 4.

The experiments were made on four forgings from one melt of 1.05 per cent carbon steel to show the effect of different methods and degrees of spheroidization upon the cutting speed in comparison with the pearlitic steel. Test log 24 (Fig. 3) represents spheroidization from an initial structure of sorbite; test log 23 A, the spheroidization from an initial structure of pearlite; test log 21, nearly 100 per cent pearlite; and test log 22, a commercially spheroidized product. Through an error of the supplier one of the four forgings was oil quenched in such a manner as to produce sorbite surrounded by envelopes of cementite, and the lathe tests made prior to retreatment give the fifth condition shown as test log 23, in Fig. 3.

With the exception of test log 23, which is not to be classed with the annealed steels, the different forgings vary in two respects: first, the amount of cementite brought out of solution, and secondly, the form in which it exists, i.e., globules, as in the spheroidized samples or plates as in pearlite. The data given in Figs. 3 and 4 show that both factors have an influence upon the cutting speed. For example, the form and distribution of the cementite in test log 22 is quite similar to that in test log 24, yet the latter, which appears to have less free ce-

mentite corresponding to the somewhat higher Brinell hardness, has an appreciably lower cutting speed. On the other hand, the Brinell hardness of test log 21 consisting of nearly 100 per cent lamellar pearlite is practically the same as that of test log 23 A, which has a mixed structure of granular and lamellar pearlite, and these structural variations likewise correspond to a measurable difference in cutting speeds.

The most desirable structure from the standpoint of rough turning is that produced by the prolonged annealing (commercial spheroidizing) applied to test log 22, in which a large cementite divorce is associated with its spheroidization. The mere absence

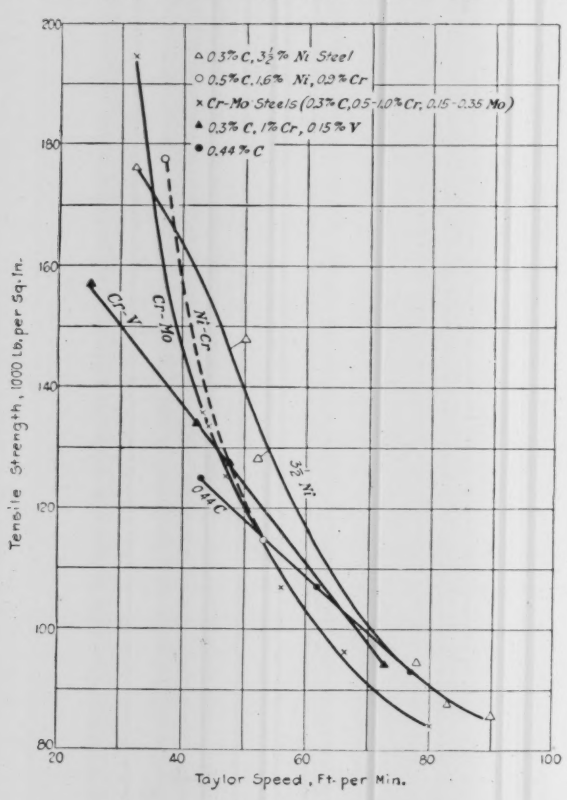
△ 0.3% C, 3½% Ni Steel
○ 0.5% C, 1.6% Ni, 0.2% Cr
× Cr-Mo Steels (0.3% C, 0.5-1.0% Cr, 0.15-0.35 Mo)
▲ 0.3% C, 1% Cr, 0.15% V
● 0.44% C
Cr-V
Cr-Mo
Ni-Cr
3½ Ni
0.44 C
Tensile Strength, 1000 Lb. per Sq. In.
Taylor Speed, Ft. per Min.

FIG. 5 RELATION OF TAYLOR SPEED TO TENSILE STRENGTH IN ROUGH TURNING QUENCHED AND TEMPERED SPECIAL STEELS

(For details of chemical compositions and heat treatments of steels cut and high-speed tools used in these tests refer to Tables 1 and 2. The lathe tests were made with the form of tool described in text, cutting "dry," with 3/16 in. depth of cut and a feed of 0.028 in. per revolution, and all results are given in terms of tool steel E, Table 1.)

of plates of cementite does not insure a high cutting speed (compare the speeds for test logs 23 A and 24 with 22), but even partial spheroidization is better than the wholly pearlitic steel.

The differences in cutting speed just referred to, and shown in Figs. 3 and 4, are not large. Comparisons may be made on the basis of the weight of the steel removed per hour when taking a 3/16-in. depth of cut at 0.028 in. feed and a speed which in each case permits a 1-hour tool life. Under such conditions it is only possible to remove about 90 per cent as much metal from the rapidly spheroidized steel (test log 24), and about 80 per cent from the pearlitic sample (test log 21), as from the steel subjected to the long-time spheroidizing treatment (test log 22).

As has already been pointed out for other types of cutting (9), the rounded globules of the hard cementite undoubtedly have a smaller tendency to cut away the tool than do the sharp or angular particles of cementite in pearlitic steels. However, from the standpoint of rough turning, where there is less danger than for other types of machining of getting the steel too soft, and where "tearing" and the character of the finish produced, etc., need not be considered, it is also important to get a large amount of the carbon out of solution. This increases the number of the cementite globules, gives more hard particles to cut away the tool, and hence tends to lower the cutting speeds; at the same time it reduces the carbon in the matrix, and, according to Taylor, should tend appreciably to increase the cutting speed. In rough turning, as is indicated by data in Figs. 3 and 4, the reduction of carbon in the matrix seems to more than counterbalance the undesirable effects from more free cementite, provided the latter is in small globules.

SPECIAL STEELS

Most attention was given to the rough turning of the special steels such as are used in automotive construction, for ordnance, railroad equipment, special machine parts, etc. The group studied consisted of the following:

1 Carbon-chromium steel containing about 0.3 per cent C and 1 per cent Cr
2 Chromium-vanadium steel containing about 0.3 per cent C, 1 per cent Cr, and 0.2 per cent V
3 High-chromium "stain-resisting" steels (perhaps better called irons) containing not more than 0.15 per cent C and more than 11 per cent Cr
4 3½ per cent nickel steel containing about 0.3 per cent C

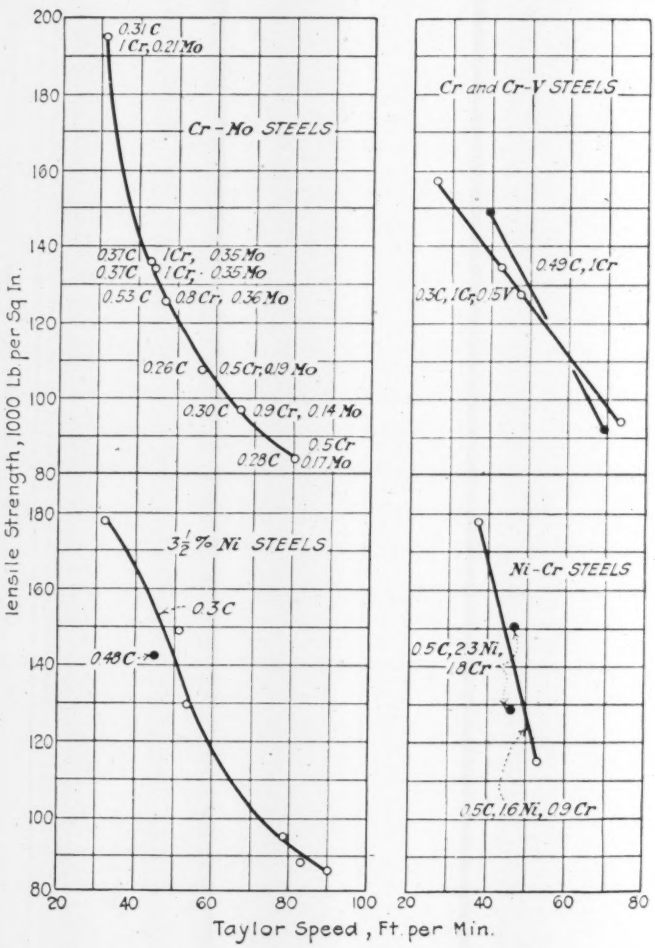
0.31 C 1 Cr, 0.21 Mo
Cr-Mo STEELS
Cr and Cr-V STEELS
0.37 C 1 Cr, 0.35 Mo
0.37 C 1 Cr, 0.35 Mo
0.53 C 0.8 Cr, 0.36 Mo
0.26 C 0.5 Cr, 0.19 Mo
0.30 C 0.9 Cr, 0.14 Mo
0.28 C 0.5 Cr 0.17 Mo
0.49 C, 1 Cr
0.3 C, 1 Cr, 0.5 V
3½% Ni STEELS
0.3 C
0.48 C
Ni-Cr STEELS
0.5 C, 2.3 Ni, 1.8 Cr
0.5 C, 1.6 Ni, 0.9 Cr
Tensile Strength, 1000 Lb per Sq In.
Taylor Speed, Ft per Min.

FIG. 6 EFFECT OF MODIFICATIONS IN CHEMICAL COMPOSITION OF VARIOUS TYPES OF STRUCTURAL ALLOY STEELS ON RELATION OF CUTTING SPEED TO TENSILE STRENGTH

(All results given in terms of tool steel E, Table 1. The lathe tests were made with form of tool described in text, cutting dry with 3/16 in. depth of cut and feed of 0.028 in. per revolution. For the heat treatments of test logs refer to Table 2.)

5 Nickel-molybdenum steel containing about 0.3 per cent C, 3¼ per cent Ni, and 0.35 per cent Mo
6 Chromium-molybdenum steels containing 0.3 per cent C, 0.5 to 1 per cent Cr, and 0.15 to 0.35 per cent Mo
7 Nickel-chromium steels containing about 0.5 per cent C, 2 to 2¼ per cent Ni, and 1 to 1¾ per cent Cr.

Lathe tests were also made on some 0.45 per cent carbon-steel forgings for comparisons with the special steels.

Comparisons of the different steels cut may conveniently be made on the basis of equal tensile strengths and the Taylor speed taken as a measure of machinability in rough turning.

To simplify discussion, all Taylor speeds are given in terms of the performance of tool steel E (Table 1). The basis of conversion of tests with other brands into the equivalent performance of high-speed steel E is described later in the report.

STRUCTURAL ALLOY STEELS

As shown in Fig. 5, a steel which permits a higher cutting speed than another at some one tensile strength does not necessarily do so at another tensile strength. Contrary to conclusions reached in previous investigations relating to other conditions of cutting, the tests here reported show that steel containing 0.3 per cent carbon and $3\frac{1}{2}$ per cent nickel have better machinability at any selected tensile strength up to about 160,000 or 170,000 lb. per sq. in. than steels of similar or higher carbon content containing 1 per cent chromium with or without vanadium or molybdenum. The same applies to a comparison between the $3\frac{1}{2}$ per cent nickel and the somewhat-higher-carbon nickel-chromium steels. However, above about 170,000 lb. per sq. in. tensile strength the order of superiority is reversed.

These results indicate that the effect of changes in the chemical composition of steel forgings upon their cutting speeds is dependent upon the tensile strength (or hardness) at which comparisons are made. Since the highest tensile-strength values considered in these tests are only produced by quenching, with or without subsequent tempering, and represent martensitic structures, changes in chemical composition may act in opposite directions, depending upon whether the steel cut is close to the fully hardened (martensitic) or the annealed or "natural" (pearlitic) condition.

From the summaries of results given in Figs. 5 and 6, it will be seen that, when approaching the annealed or natural condition, increase in carbon or the addition of any of the special elements considered has a tendency to lower the cutting speed.

For example, Fig. 5 shows that at a tensile strength of about 95,000 lb. per sq. in. the chromium-molybdenum steel has a lower cutting speed than the chromium-vanadium steel. Since both types have similar proportions of carbon and chromium (refer to Table 2 and Fig. 6), the lower cutting speed of the chromium-molybdenum steel may be ascribed to the molybdenum.

TABLE 2 CHEMICAL COMPOSITION, HEAT TREATMENT, AND OTHER DETAILS OF THE MATERIALS CUT IN THE LATHE TEST

Test Log No.	Approx. dimensions of test logs: Outside diam., in.	Approx. dimensions of test logs: Diam. of hole,[a] in.	Supplier	Supplier's melt number	Chemical composition, per cent[b]: C	Mn	P	S	Si	Ni	Cr	V	Mo	Cu	Heat treatment[c] (all temperatures given in deg. fahr.)
1	14	5½	D	P983-19	0.26	0.57	0.041	0.035	0.15	3.81	....	....	....	0.11	1650 emulsion; 1560 water; 1200.
2	14	5½	D	P983-8	0.26	0.57	0.041	0.035	0.15	3.81	....	....	....	0.11	1650 emulsion; 1560 water; 1340.
3	7¼	..	D	S	0.44	0.62	0.014	0.032	0.14	0.27	....	....	....	trace	Tested as received; exact treatment not known.
5	7¼	..	D	53560	0.44	0.62	0.014	0.032	0.14	0.27	....	trace	....	trace	1560 emulsion; 1020.
6	13	..	A	8403	0.30	0.81	0.018	0.022	0.16	....	0.80	....	0.14	....	1580 emulsion; 1060.
7	8½	..	A	7846	0.53	0.73	0.017	0.020	0.20	....	0.80	....	0.36	....	1500 emulsion; 1240.
8	9½	..	C	6387	0.28	0.45	0.016	0.027	0.11	....	0.51	....	0.17	....	1600 emulsion; 1180.
9	12¾	..	A	5373	0.29	0.62	0.018	0.020	0.23	....	0.85	0.17	....	....	1680 water; 1230.
10	10½	..	B	15248	0.37	0.60	.....	.....	....	....	1.00	....	0.35	....	1540 emulsion; 1040.
10A	5½	..	B	15248	0.37	0.60	.....	.....	....	....	1.00	....	0.35	....	1530 water; 1000.
11	7½	1¾	C	5379	0.32	0.68	0.017	0.031	0.20	....	1.02	0.15	....	....	1720 water; 940.
11A	5½	1¾	C	5379	0.32	0.68	0.017	0.031	0.20	....	1.02	0.15	....	....	1800 water; 450.
12	9½	4¼	D	R70-4	0.28	0.62	0.040	0.019	0.25	3.11	....	....	....	0.28	1540 water; 960.
12A	7	4¼	D	R70-4	0.28	0.62	0.040	0.019	0.25	3.11	....	....	....	0.28	1560 water; 900.
13	10½	..	A	1603	0.32	0.61	0.017	0.020	0.18	3.27	....	....	0.36	....	1560 emulsion; 1420.
14	7	..	D	1320	0.53	0.54	0.017	0.014	0.26	2.26	1.78	....	....	0.13	1650 air; 1000.
14A	5½	..	D	1320	0.53	0.54	0.017	0.014	0.26	2.26	1.78	....	....	0.13	1520 emulsion; 1140.
15	12½	..	A	XXX	0.49	0.78	0.017	0.029	0.21	....	0.93	....	....	....	1550 furnace cool to 1275; soak and slow cool.
15A	5½	..	A	XXX	0.49	0.78	0.017	0.029	0.21	....	0.93	....	....	....	1640 water; 920.
16	8	..	H	.....	0.18	0.50	0.010	0.040	0.04	....	....	....	....	....	Tested as received; exact treatment not known.
17	12	4	D	R564-1	0.31	0.56	0.040	0.027	0.31	3.27	....	....	....	0.26	1460 furnace cool.
18	12	4	D	R564-1	0.31	0.56	0.040	0.027	0.31	3.27	....	....	....	0.26	1460 furnace cool.
19	5½	2¾	E	.....	0.26	0.46	.....	.....	....	....	0.53	....	0.19	....	Water quenched; not tempered; exact treatment not known.
20	2	..	H	SS33	0.28	0.55	0.026	0.038	0.11	3.33	0.12	....	....	0.15	1560 water; 660.

[a] If hollow bored.
[b] With exception of logs 16, 27A, and 29, analyzed at the Bureau of Standards, compositions are those reported by the respective producers.
[c] Where the heating times are not given they are not known exactly. The emulsion referred to consisted of 5 per cent rapeseed oil, 15 per cent paraffin oil, and 80 per cent water containing 1 per cent sodium carbonate.

Test Log No.	Approx. dimensions of test logs: Outside diam., in.	Approx. dimensions of test logs: Diam. of hole,[a] in.	Supplier	Supplier's melt number	Chemical composition, per cent[b]: C	Mn	P	S	Si	Ni	Cr	V	Mo	Cu	Heat treatment[c] (all temperatures given in deg. fahr.)
21	9	2½	F	E517	1.05	0.30	0.024	0.012	0.20	nil	trace	....	....	....	1500—12 hr.; cool in 1½ hr. to 1110; slow cool in furnace.
22	9	2½	F	E517	1.05	0.30	0.024	0.012	0.20	nil	trace	....	....	....	1345—18 hr.; cool in 5 hr. to 1185; slow cool in furnace.
23	9	2½	F	E517	1.05	0.30	0.024	0.012	0.20	nil	trace	....	....	....	1500—12 hr. furnace cool; 1400—2 hr. oil quench to 1095; air cool.
23A	9	2½	F	E517	1.05	0.30	0.024	0.012	0.20	nil	trace	....	....	....	1400—2 hr. slow cool (40 hr. to reach 1095).
24	9	2½	F	E517	1.05	0.30	0.024	0.012	0.20	nil	trace	....	....	....	1500—12 hr. furnace cool; 1560—3 hr. water; 1300—3 hr. air cool.
25	6¾	2¼	A	5011	0.52	0.40	0.009	0.016	0.27	1.64	0.92	....	....	....	1575—3½ hr. oil; 850—3½ hr.
25A	4¾	2¼	A	5011	0.52	0.40	0.009	0.016	0.27	1.64	0.92	....	....	....	1575—3½ hr. oil; 1325—2 hr.
26	6¾	2¼	A	7892	0.48	0.67	0.016	0.016	0.21	3.42	0.15	....	....	....	1575—3½ hr. oil; 750—3 hr.
27A	5¼	2¼	A	5103	0.31	0.55	0.016	0.022	0.18	....	1.00	....	0.21	....	1575—1 hr. water; 730—2 hr.
29	7	..	H	.....	0.33	0.66	0.016	0.060	0.19	....	....	....	....	....	Tested as received; exact treatment not known.
30	2¼	..	H	SS30A	0.29	0.50	0.024	0.032	0.21	0.28	1.03	0.21	....	0.13	1650—1 hr. water; 670—1 hr.
30A	2¼	..	H	SS30A	0.29	0.50	0.024	0.032	0.21	0.25	1.03	0.21	....	0.13	1650—1 hr. water; 670—1 hr.
31	6¾	2¼	A	5011	0.52	0.40	0.009	0.016	0.27	1.64	0.92	....	....	....	1575—3½ hr. oil; 850—3½ hr.
32	3¾	..	D	53560	0.44	0.62	0.014	0.032	0.14	0.27	....	trace	....	....	1560—2 hr. water; 550—3 hr.
33	4	..	D	53560	0.44	0.62	0.014	0.032	0.14	0.27	....	trace	....	....	1560—2 hr. water; 550—3 hr.
34	3	..	K	.....	0.15	0.42	0.013	0.030	0.23	0.35	24.4	....	....	....	Rolled at about 1850; water quench from rolling heat (about 1650); slightly warmed for straightening.
35	3	..	J	.....	0.09	0.48	0.011	0.011	0.24	....	12.3	....	....	....	1290—1 hr. air cool.
36	14	..	F	7/275	0.40	0.74	0.028	0.039	0.24	3.32	nil	....	....	....	1600—12 hr. air cool to 1250; held 10 hr. furnace cool.

[a] If hollow bored.
[b] With exception of logs 16, 27A, and 29, analyzed at the Bureau of Standards, compositions are those reported by the respective producers.
[c] Where the heating times are not given they are not known exactly. The emulsion referred to consisted of 5 per cent rapeseed oil, 15 per cent paraffin oil, and 80 per cent water containing 1 per cent sodium carbonate.

The chromium-vanadium steel, in turn, has a somewhat lower cutting speed than the 3½ per cent nickel steel. No direct comparisons are available between the latter and plain carbon steel of similar carbon content, but an idea may be obtained of the effect of nickel by comparison of results in cutting test logs 3 and 1. These have practically the same tensile strength (respectively 92,800 and 94,600 lb. per sq. in. as shown in Table 3) and practically identical cutting speeds (given in Table 5 as respectively 77 and 78 ft. per min.). Test log 3 contains 0.44 per cent carbon, while test log 1 contains 0.26 per cent carbon and 3.8 per cent nickel. Since increase in carbon has been shown to reduce the cutting speed, the equality in these two steels means that the addition of 3½ per cent of nickel has had about the same effect as an increase from 0.26 to 0.44 per cent of carbon. This is not intended as a quantitative comparison but merely to demonstrate that nickel has a tendency to reduce the cutting speeds. However, the reduction produced by 3½ per cent of nickel is less than that from 1 per cent of chromium.

TABLE 3 AVERAGE TENSILE PROPERTIES OF THE TEST LOGS AS DETERMINED FROM SPECIMENS CUT LONGITUDINALLY AT DIFFERENT DIAMETERS TO REPRESENT THE METAL REMOVED IN THE CUTTING TESTS

Log No.	Type of steel	No. of tests made	Prop. limit, 1000 lb. per sq. in.	Yield point, 1000 lb. per sq. in.	Tensile strength, 1000 lb. per sq. in.	Breaking strength, 1000 lb. per sq. in.	Elong. in 2 in., per cent	Red. of area, per cent	Area under stress-strain curve [b] Sq. in.	Area under stress-strain curve [b] Compared to log 1, per cent	Energy required to break the specimen, in-lb. per cu. in.	Maximum variation from the mean value of tensile strength, per cent	
1	3½% Ni	4	65.8	69.5	94.6	169 8	25.9	60.9	1.44	100	1730	+2.5	−1 8
2	3½% Ni	6	41.1	49.2	85.6	144.2	27.3	55.1	1.46	101	1750	+1.6	−3.7
3	0.44% C	5	51.7	56.4	92.8	167.5	25.8	55.2	1.52	106	1820	+5 6	−3 0
5	0.44% C	6	62.3	66.3	107.0	162.8	21.6	47.6	1.36	94	1630	+8.4	−4 7
6	Cr-Mo	4	62.2	73.6	96.4	182.6	23.1	64.9	1.30	90	1560	+5.3	−5 1
7	Cr-Mo	4	83.5	95.3	125 0	211.9	21.4	58.8	1.62	112	1940	+6.0	−8.4
8	Cr-Mo	5	50.7	53.8	83.7	157.2	26.7	57.7	1.37	95	1640	+2 8	−1 4
9	Cr-V	5	58.3	64.1	93.6	180.7	24.4	65.1	1.32	92	1580	+6.8	−4 7
10	Cr-Mo	4	97.0	110.0	133.5	217.8	18.2	57.3	1.47	102	1760	+4.9	−4 9
10A	Cr-Mo	4	79.3	117.1	135.5	206.4	15.4	48.3	1.37	95	1640	+14.4	−12.2
11	Cr-V	4	88.5	105.0	127.0	201.2	18.0	54.1	1.39	97	1670	+2.8	−2 6
11A	Cr-V	4	63.0	117.0	134.0	195.2	13.1	43.5	1.15	80	1380	+1.1	−1.1
12	3½% Ni	6	86.9	106.1	128.7	171.1	13.2	35.5	1.28	89	1540	+8.5	−5.2
12A	3½% Ni	2	129.5	138.2	148.8	176.0	10.2	23.0	0.96	67	1150	+0.5	−0.5
13	Ni-Mo	6	59.3	93.0	127.7	175.4	16.2	37.6	1.57	109	1880	+1.0	−1.3
14	Ni-Cr	4	59.2	70.3	128.0	175.4	18.9	39.4	1.63	113	1960	+4.7	−2.4
14A	Ni-Cr	2	127.0	135.5	150.2	226.2	18.5	49.8	1.75	122	2100	+0.2	−0 2
15	C-Cr	4	33.5	37.9	91.9	124.4	19.6	30.2	1.28	89	1540	+1.2	−1.0
15A	C-Cr	2	95.0	118.3	148.4	180.9	12.3	26.3	1.26	88	1510	+0.9	−0.9
16	0.18% C	4	24.5	31.6	66.4	110.0	34.9	51.8	1.40	97	1680	+4.2	−5 9
17	3½% Ni	2	51.5	53.2	87.3	149.6	29.2	54.2	1.62	112	1940	0	0
18	3½% Ni	2	51.5	53.2	87.3	149.6	29.2	54.2	1.62	112	1940	0	0
19	Cr-Mo	2	45.0	88.8	107.3	184.4	18.0	56.5	1.15	80	1380	+0.3	−0.3
20	3½% Ni	4	115.0	162.9	176.4	191.8	3.8	10.1	0.50	35	600	+5.2	−5.7
21	1.05% C	1	42.5	45.2	92.9	92.9	....	....	....	....	....	.....	.....
22	1.05% C	1	31.0	42.0	87.5	113.5	23.5	25.9	1.52	106	1820	.....	.....
23	1.05% C	1[a]	67.5	80.0	132.0	136.7	3.0	3.5	.38	26	460	.....	.....
23A	1.05% C	1	50.0	51.0	99.0	106.4	6.0	6.7	....	....	....	.....	.....
24	1.05% C	1	65.0	66.0	101.0	149.5	23.5	41.4	1.60	111	1920	.....	.....
25	Ni-Cr	4	123.5	162.8	177.5	234.8	11.0	37.5	1.27	88	1520	+6.9	−5.9
25A	Ni-Cr	2	76.0	81.2	114.5	202.8	23.0	59.9	1.55	108	1860	+0.9	−0.9
26	3½% Ni	4	86.5	120.6	141.3	208.4	17.5	46.4	1.28	89	1540	+3.2	−4.1
27A	Cr-Mo	3	127.3	181.5	194.7	250.3	10.0	38.0	1.22	85	1460	+3 0	−2.4
29	0.33% C	2	31.8	35.2	69.8	121.8	25.0	52.3				+0.3	−0 3
30A	Cr-V	3	94.7	141.3	157.0	236.3	12.8	49.9	1.22	85	1460	+5.8	−4.7
31	Half of log No. 25; refer to tests above.												
32 } 33 }	0.44% C	4	74.6	87.4	124.8	161.8	17.0	33.4	1.33	92	1600	+1.4	−1.4
34	Chrome-iron	2	49.5	55.3	77.5	143.7	31.5	60.9	1.45	101	1740	0	0
35	Stainless iron	2	61.3	75.2	92.8	198.3	26.0	74.4	1.26	88	1510	+0.8	−0.8
36 } 37 }	3½% Ni	2	49.8	58.4	99.2	143.0	24.5	39.8	1.48	103	1780	+0.3	−0.3

[a] This specimen cut at 90 deg. to the long axis of the forging.
[b] Area in square inches was obtained from charts in which 1 in. = 1200-lb. load and 1 in. = 0.4-in. strain.

TABLE 4 SUMMARY OF TESTS SHOWING THAT THE CUTTING SPEED IN DRY ROUGH TURNING IS INVERSELY PROPORTIONAL TO THE 1/7 POWER OF TOOL LIFE

(All tests made dry with 0.028-in. feed, $\frac{3}{16}$-in. depth, and the form of tool described in the text)

Test log No.	Type of steel	Tensile strength, lb. per sq. in.	Tools used: Type of high speed steel	Tools used: Lot	Cutting speed, ft. per min.	Average tool life in minutes: Determined experimentally	Average tool life in minutes: Computed [c]	Assigned value of the constant c in $VT^{\frac{1}{7}} = c$
2	3½% Ni	85 600	High-tungsten–low-vanadium	E	80	45.9	44.5	137.6
					90	19.5	19.5	
					105	7.1	6.6	
1	3½% Ni	94,600	High-tungsten–low-vanadium	E	70	43.6	42.2	119.5
					80	16.6	16.6	
					90	7.1	7.3	
6	Cr-Mo	96,400	Low-tungsten–high-vanadium	H	70	16.7	16.9	104.8
					80	7.1	6.6	
					90	2.8	2.9	
9	Cr-V	93,600	High-tungsten–low-vanadium	E	70	31.5	25.2	111.0
.9					80	9.9	9.9	
					90	4.6	4.3	
5	0.44% C	107,000	High-tungsten–low-vanadium,	E	70	7.3	7.3	93.0
					80	3.7	2.9	
			High-tungsten–cobalt	G	70	11.6	11.6	99.4
					80	6.6	4 6	
14A	Ni-Cr	150,200	High-tungsten–low-vanadium	I	45	6.5	6.5	58.8
					53	2.5	2.1	
[a]	3½% Ni	115/125,000	Low-tungsten–high-vanadium	C	45	43.4	47.7	78.2
					50	24.7	22.8	
					60	6.4	6.4	
					70	2.2	2.2	
[a]	3½% Ni	115/125,000	Low-tungsten–cobalt	A	50	32.4	33.4	82.6
					55	16.1	17.3	
					60	9.9	9.3	
					70	3.3	3.2	
[a]	3½% Ni	115/125,000	High-tungsten–low-vanadium	D	40	(83.2) [b]	77.6	74.5
					45	32.8	34.1	
					50	15.0	16.3	
					60	5.3	4.6	
					70	1.4	1.5	
[a]	3½% Ni	115/125,000	High-tungsten–cobalt	B	50	34.2	30.4	81.5
					55	14.6	15.6	
					60	7.6	8.5	
					70	3.1	2.9	

[a] These tests, taken from a previous investigation [see reference (2)], were made on several logs; the average values of tool life shown in the table are based on a like number of tests at each cutting speed on each test log.
[b] Where tool life is given in brackets, it is approximate, as some of the tools lasted too long to run to failure.
[c] Computed from $VT^{\frac{1}{7}} = c$ = values shown in next column.

In steels approaching the fully hardened (martensitic) condition the cutting speeds depend upon how the chemical composition affects the characteristics of the martensite or other products produced by heat treatment. The structures produced by quenching steel containing 0.3 per cent carbon and 1 per cent chromium have a higher ratio of cutting speed to tensile strength than those in 0.44 per cent carbon steel, but not so high as those in the $3\frac{1}{2}$ per cent nickel steel. The ratios for the latter are likewise not so high as those in the chromium-molybdenum or the nickel-chromium steels.

Elements which cause a lowering in the cutting speeds of the annealed steels may improve the cutting speeds when considering higher tensile strengths approaching those of the martensitic condition. The most effective of the special elements in the different steels cut are the combinations of nickel and chromium or chromium and molybedenum, but carbon increase may also be beneficial.

TABLE 5 TAYLOR SPEEDS FOR VARIOUS STRUCTURAL STEELS

Test log			Taylor speed for the high-speed steels indicated [a]					
		Tensile strength, 1000	High-tungsten		Low-tungsten		High-tungsten, Cobalt	
No.	Steel type	lb. per sq. in.	Lot	Ft. per min.	Lot	Ft. per min.	Lot	Ft. per min.
	Carbon Steels							
16	0.18% C	66.4	M	108	L	107	..	..
29	0.3% C	69.8	N	90	..	....	..	..
3	0.44% C	92.8	E	77	H	76	G	81
5	0.44% C	107.0	E	62	H	61	G	66
32 & 33	0.44% C	124.8	E	43	..	....	..	..
21	1.05% C	92.9	I	44	..	....	..	..
22	1.05% C	87.5	I	57	..	....	..	..
23	1.05% C	132.0	I	27	..	....	..	..
23A	1.05% C	99.0	I	46	..	....	..	..
24	1.09% C	101.0	I	49	..	....	..	..
	Chromium Steels							
15	1% Cr	91.9	E	69	H	67	G	74
15A	1% Cr	148.4	I	29	..	....	K	36
34	Chrome-iron	77.5	E	71	..	....	..	..
35	Stainless-iron	92.8	E	69	..	....	..	..
	Chromium-Vanadium Steels							
9	Cr-V	93.6	E	73	H	76	G	75
11	Cr-V	127.0	E	47	H	46	G	54
11A	Cr-V	134.0	I	32	..	....	K	41
30A	Cr-V	157.0	I	15+	..	....	..	..
	Nickel Steels							
2	$3\frac{1}{2}$% Ni	85.6	E	90	H	85	G	94
17 & 18	$3\frac{1}{2}$% Ni	87.3	I	73	L	78	..	..
1	$3\frac{1}{2}$% Ni	94.6	E	78	..	....	G	81
36	$3\frac{1}{2}$% Ni	99.2	..	..	L	69	P	57
..	$3\frac{1}{2}$% Ni	120.0	D	49	C	51	B	53
12	$3\frac{1}{2}$% Ni	128.7	E	52+	H	52	G	56
26	$3\frac{1}{2}$% Ni	141.3	I	35	..	....	..	..
12A	$3\frac{1}{2}$% Ni	148.8	I	41	..	....	K	46
20	$3\frac{1}{2}$% Ni	176.4	I	22	..	....	..	..
	Nickel-Chromium Steels							
25A	1.6 Ni, 0.9 Cr	114.5	E	53	..	....	..	..
14	2.3 Ni, 1.8 Cr	128.0	E	46	H	46	G	52
14A	2.3 Ni, 1.8 Cr	150.2	I	38	..	....	K	42
25	1.6 Ni, 0.9 Cr	177.5	I	27	..	....	K	30
	Nickel-Molybdenum Steels							
13	$3\frac{1}{4}$ Ni, 0.35 Mo	127.7	E	50	H	46+	G	52
	Chromium-Molybdenum Steels							
8	0.5 Cr, 0.17 Mo	83.7	E	80	H	83	G	85
6	0.9 Cr, 0.14 Mo	96.4	E	66+	H	68	G	75
19	0.5 Cr, 0.19 Mo	107.3	I	46	..	....	..	..
7	0.8 Cr, 0.36 Mo	125.0	E	47+	H	53	G	50
10	1.0 Cr, 0.35 Mo	133.5	E	44+	H	45	G	49
10A	1.0 Cr, 0.35 Mo	135.5	I	33+	..	....	K	41
27A	1.0 Cr, 0.21 Mo	194.7	I	22+	..	....	..	..

[a] For dry-cutting at $\frac{3}{16}$-in. depth and a feed of 0.028 in. per revolution with the form of tool described in the text. Calculated from life tests by means of Equation [2] of the text.

TABLE 6 EFFECT OF METHOD OF HEAT TREATMENT ON THE CUTTING SPEEDS OF STEEL FORGINGS HAVING EQUAL TENSILE STRENGTHS

(Tests made dry at $\frac{3}{16}$-in. depth and 0.028-in. feed)

Test Log No.	Steel cut: Type composition, per cent	Heat treatment (all temperatures given in deg. fahr.)	Tensile strength, 1000 lb. per sq. in.	Taylor speed, ft. per min., when using tool steel: E	G
	Comparison of Different Methods of Quenching and Tempering				
10	0.37 C, 1 Cr, 0.35 Mo	1540 emulsion; 1040	133.5	44	49
10A	0.37 C, 1 Cr, 0.35 Mo	1530 water; 1000	135.5	44[a]	51[b]
11	0.32 C, 1 Cr, 0.15 V	1720 water; 940	134.0[c]	45[c]	54
11A	0.32 C, 1 Cr, 0.15 V	1800 water; 450	134.0	43[a]	51[b]
6	0.30 C, 0.8 Cr, 0.14 Mo	1580 emulsion; tempered around 1100	107.0	58[f]	....
19	0.26 C, 0.5 Cr, 0.19 Mo	Water quenched; not tempered	107.3	57[a]	...
	Comparison of Quenched and Tempered Steels with Annealed Steels				
2	0.26 C, 3.8 Ni	1650 emulsion; 1340	85.6	90	94
17	0.31 C, 3.3 Ni	1460 furnace cool	87.3	84[a, d]	...
9	0.29 C, 0.85 Cr, 0.17 V	1680 water; 1230	93.6	73	75
15	0.49 C, 0.93 Cr	1550 furnace cool to 1275; soak and slow cool	91.9	69	74
..	0.3 C, 3.1 to 3.8 Ni	Quenched and tempered	100.0	73[e]	...
36	0.4 C, 3.3 Ni	1600 air cool to 1250; soak and furnace cool	99.2	75[f]	...

[a] Estimated from the known difference in cutting speeds of tool steels E and I. Refer to Fig. 6.
[b] Estimated from the known difference in cutting speeds of tool steels G and K. Refer to Fig. 6.
[c] Estimated from tests at a tensile strength of 127,000 lb. per sq. in.
[d] Estimated from the known difference in cutting speeds of tool steels E and L.
[e] Estimated from tests at tensile strengths of 94,600 and 128,700 lb. per sq. in.
[f] Estimated from tests at tensile strengths of 96,400 lb. per sq. in.

Effect of Method of Heat Treatment on the Cutting Speed

As shown in Table 6, the cutting speed at a given tensile strength is not appreciably affected by the method of heat treatment by which this strength is produced. The six sets of experiments were made on several types of steel having tensile strengths between 85,000 and 135,000 lb. per sq. in., and consideration is given to variations in quenching and tempering temperatures, coolants used in hardening, etc.

Perhaps the most interesting tests are those which show that a single cooling, as, for example, accelerated furnace or air cooling, gives substantially the same cutting speed as quenching followed by tempering, provided these two methods give the same tensile strength. Thus it makes no great difference by what method a given tensile strength is produced in a steel in so far as the cutting speed is concerned. This should not be taken as approval of quenching without tempering, as such procedure, even in small sections, leaves hardness gradients which are undesirable from a practical viewpoint.

Stain-Resisting Iron Alloys

At a tensile strength of about 93,000 lb. per sq. in., stainless iron, containing about 0.1 per cent carbon and $12\frac{1}{2}$ per cent chromium, has practically the same cutting speed as steel containing 0.5 per cent carbon and 1 per cent chromium (test log 15, Table 5) and a steel containing 0.3 per cent carbon, 1 per cent chromium, and 0.2 per cent vanadium (test log 9, Table 5), provided the two latter are quenched and tempered to produce the same tensile strength.

Since the method of treatment by which a given strength is produced has been shown to have no appreciable effect upon the cutting speed, this indicates that large amounts of chromium do not, in the absence of carbon, seriously affect the rough-turning properties of steels. Chromium in large amounts is supposed to be partly in solid solution in the ferrite, and in this condition probably has a small effect upon the cutting speed. In addition there is only a very small amount of carbon present in this stainless iron, with which chromium can form the very hard carbides which tend to wear away the cutting tools and thus reduce the cutting speeds.

The chrome iron, containing about 0.15 per cent carbon and $24\frac{1}{2}$ per cent chromium, with a tensile strength of 78,000 lb. per sq. in. has about the same cutting speed as the stainless iron with a tensile strength of 93,000 lb. per sq. in. or the 0.44 per cent carbon steel with a tensile strength of 100,000 lb. per sq. in. (Refer to Table 5.) Thus the higher proportions of both chromium and carbon in the "chrome iron," as compared with the stainless iron, have reduced the cutting speeds (compared on the basis of equal tensile strength), but not to a very marked degree.

Aside from demonstrating that these high-chromium iron alloys can quite readily be rough turned, these tests show that the reduction in cutting speeds produced by large additions of chromium to iron is dependent very largely upon the carbon present.

Interchangeability of the Special Steels

Different combinations of composition and heat treatment may be used to produce at the same time similar mechanical test values and cutting speeds, but interchangeability is somewhat more restricted under such conditions than when considering only such factors as tensile strength, endurance limits, etc., and interchangeability in one range of tensile strength or hardness does not mean interchangeability in other ranges.

While certain well-defined differences in cutting speed have been found for the various structural alloy steels heat-treated to show equal tensile strengths, these are no greater, in most cases, than differences which may ordinarily arise from variations in the quality of the steel from which the tools are made. High-speed steel I, which is practically identical in chemical composition with steel E (Table 1) in so far as the elements ordinarily determined are concerned, and which when made into tools was subjected to the same heat treatments, has a consistently lower cutting speed than tool steel E. As shown by comparison of Figs. 5 and 7, this difference is as great as most of the differences in cutting

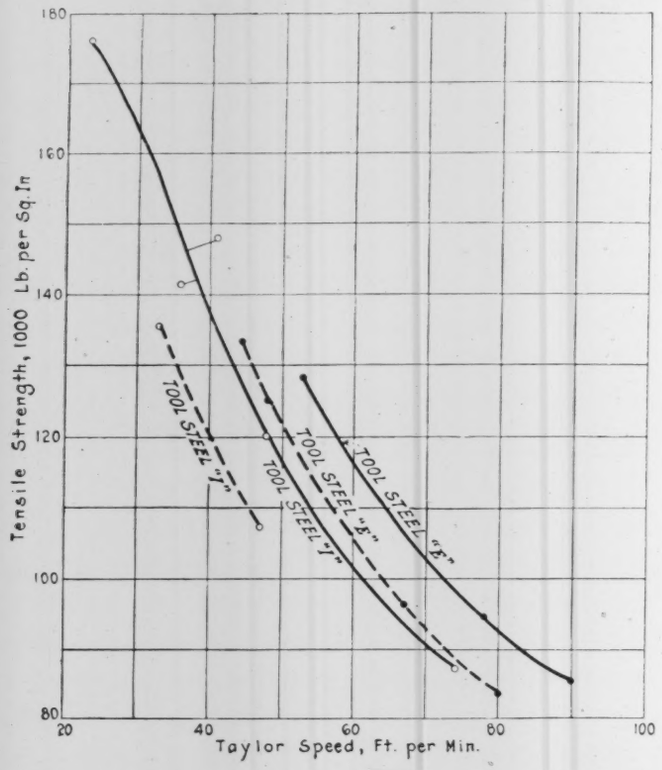

FIG. 7 COMPARISON OF CUTTING SPEEDS OF TWO LOTS OF HIGH-SPEED STEEL OF SIMILAR CHEMICAL COMPOSITION WHEN SUBJECTED TO SAME HEAT TREATMENTS

(Solid lines denote tool tests on nickel steels. Dotted lines, tool tests on chromium-molybdenum steels.
Note that cutting speed of steel E is equal approximately to that of steel I plus 10, when cutting both hard and soft steels.)

speed arising from variations in the materials cut. Since both high-speed steels represent commercial products obtained in the open market from reputable manufacturers, it is clear that any benefits derived from selection of the steel machined may be completely counteracted by neglect to guard the quality (and likewise the treatment) of the high-speed steel used.

EFFECT OF FEED AND DEPTH OF CUT ON THE CUTTING SPEED FOR DIFFERENT STEELS

Taylor found that the relation between the cutting speed giving a fixed tool life, the feed, depth of cut, and radius of nose of the tools could be approximately represented by the empirical equation

$$V = \frac{\text{constant}\left(1 - \frac{8}{7(32r)}\right)}{F^{2/5 + \frac{2.12}{5+32r}}\left(\frac{48}{32r}D\right)^{2/15 + 0.06\sqrt{32r}} + \frac{0.8(32r)}{6(32r)+48D}} \quad \ldots\ldots [3]$$

in which V = cutting speed for selected tool life, ft. per min.
F = feed in inches per revolution
D = depth of cut, in inches
r = nose radius of the tool, in inches.

As already pointed out, only one form of tool was used ($^1/_4$ by $^1/_2$ in. with $^1/_8$-in. nose radius), and no check was made on the validity of this equation with change of nose radius when cutting high-strength steels.

For the tool radius used Equation [3] reduces to:

$$V = \frac{\text{constant } (0.714)}{F^{0.6356}\,(12D)^{0.2533 + \frac{3.2}{24+48D}}} \quad \ldots\ldots [4]$$

For the $^3/_{16}$-in. depth of cut and the 0.028-in. feed used in the experiments described previously, Equation [4] reduces to

$$\text{constant} = 0.1922V \quad \ldots\ldots [5]$$

This equation was used to calculate the constant in Equation [4] for all these tests.

Two series of tests were then made on test log 36 ($3^1/_2$ per cent nickel steel, tensile strength approximately 100,000 lb. per sq. in.), one at a constant feed of 0.028 in. per revolution and depths of cut ranging from $^1/_8$ to $^7/_{16}$ in. and the other at a constant depth of cut of $^3/_{16}$ in. and feeds ranging from 0.015 to 0.092 in. per revolution. The results are shown in Fig. 8.[5] On this same chart (Fig. 8) are drawn curves computed from Taylor's Equation

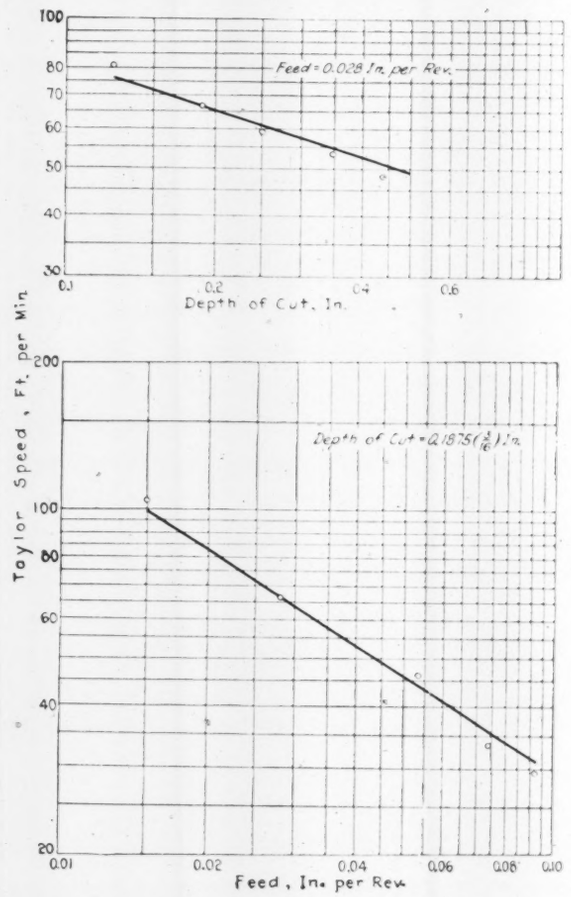

FIG. 8 EFFECT OF FEED AND DEPTH OF CUT ON CUTTING SPEED

(Test made with tool steel P on test log 36. Solid lines represent Equation [6]; circles represent results of lathe tests. Note that logarithmic coördinates are used.)

[3] with the constant computed from the previous tests. The agreement is as close as could be expected, showing that Taylor's equation represents these tests with good accuracy.

Additional tests were then made upon four different test logs covering steels of from 66,000 to 177,000 lb. per sq. in. tensile strength, but covering in each case only one or two variations in speed or depth of cut.

In each case the cutting speed for 1-hour tool life has been computed in two ways: first, directly from the observations by means of Equation [2], and secondly, from the observations at standard feed (0.028 in.) and depth of cut ($^3/_{16}$ in.) by means of Equation [2] and Taylor's Equation [4]. The agreement in all cases is as close as could be expected.

[5] And in Table 9 of the complete paper.

GRAPHIC REPRESENTATION OF THE RELATION BETWEEN FEED, DEPTH, STEEL CUT, AND THE SPEED GIVING 1-HOUR TOOL LIFE

Provided the tool life is known at some one speed, feed, and depth of cut, computations for a selected tool life (for example, 1 hour) only require the use of Equations [2] and [4]. They are, however, tedious because of the form of Equation [4], and for this reason the chart reproduced in Fig. 9 was constructed, embodying the application of Taylor's equation (in the form of Equation [4]) to the results of the present experiments. This gives in a form adapted for quick use the cutting speeds permitting a 1-hour tool life, when taking different cuts on various steels with the $^1/_4$-in. by $^1/_2$-in. lathe tools used in this investigation. By using logarithmic rectangular coördinates for depth of cut and feed, the equal-speed lines are nearly straight, and the effect of the tools and the material cut is provided for by simply shifting identical scales of speed up or down. Speed scales, properly located, are provided for many of the materials tested. Those applying to cutting steels having tensile strengths of 135,000 lb. per sq. in. or over are based on the results obtained with tool steel I, Table 1, while those applying to cutting lower-strength steels are based on the results obtained with tool steel E (Table 1). In addition, a sliding speed scale is provided (at the left). This may be cut out, and when slid up or down to such a position that it gives correctly the speed for 1-hour tool life at one depth of cut and feed, it will then indicate corresponding speeds for other cuts. The proper location for a given "quality" of tool and metal cut requires only a knowledge of the speed for some one feed and depth.

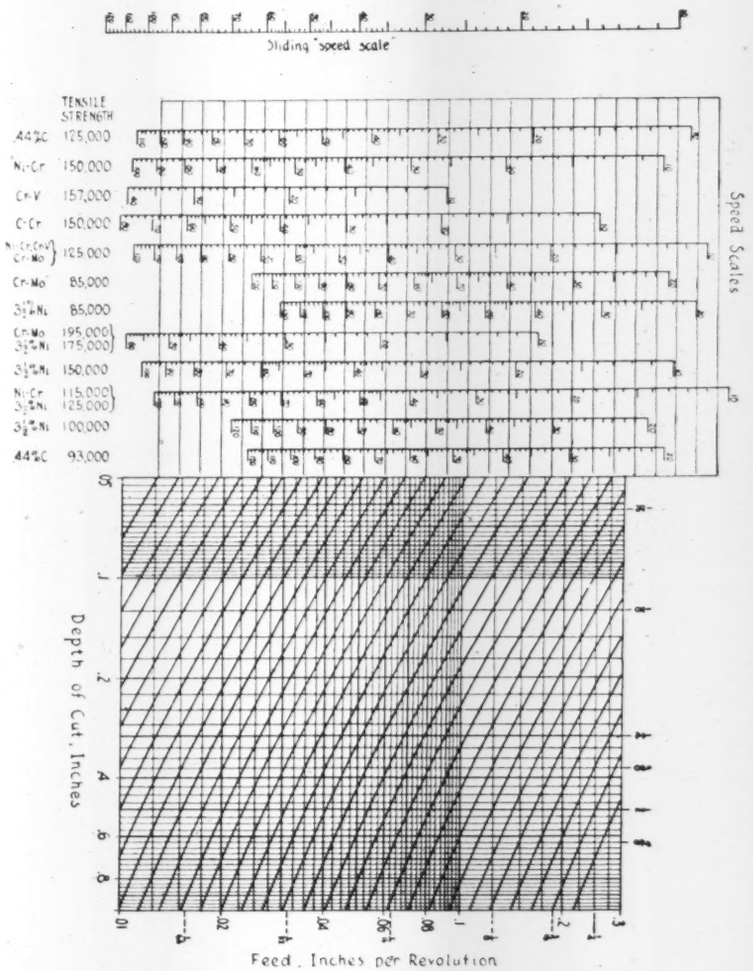

FIG. 9 CUTTING-SPEED CHART FOR SELECTED SIZE AND FORM OF TOOLS USED IN EXPERIMENTS

(This gives cutting speed permitting a tool life of one hour in dry turning various steels at different feeds and depths. Below each speed scale will be found type of steel cut and its tensile strength. Refer to text for a discussion of use of chart.)

In using the chart, Fig. 9, first find the point corresponding to the selected feed and depth of cut; follow the corresponding curved speed line to the left edge of the feed-depth chart, and then follow the horizontal to the speed scale applying to the particular steel to be cut. Too great a degree of accuracy in predictions should not be expected. It is advisable to restrict applications of Fig. 9 to severe service, i.e., conditions truly characterized as rough turning. However, it should be kept in mind that what are light cuts on a soft steel may represent severe service and rough turning for a much harder steel; for this reason the chart in Fig. 9 has included a wide range in feeds and depths.

FIG. 10 TYPICAL FAILURES OF ROUGHING LATHE TOOLS IN BREAKDOWN TESTS

(Note the rubbing off of the nose and the "gutter" or groove worn on the top surface of the tools.)

FACTORS ORDINARILY DETERMINED IN CUSTOMARY HARDNESS AND TENSION TESTS OF STEELS CUT NOT QUANTITATIVE CRITERIA OF THEIR CUTTING SPEEDS

The following equation represents the empirical relations derived by Taylor between the cutting speed and the tensile properties of the steel cut:

$$V = \frac{125\left(1 - \frac{215}{(15 + E)^2}\right)}{\sqrt{\left(\frac{S}{10{,}000} - 3\right)} - 0.9} \qquad [6]$$

in which V = speed in ft. per min. which causes the tool to fail in exactly 20 min.
S = tensile strength in lb. per sq. in.
E = per cent elongation in 2 in.

This is characterized as only a partial guide which does not, for either very hard or very soft steels, give values very close to the experimental observations.

There is no reason why any one of the factors determined in the customary hardness or tension tests should be a quantitative criterion of the cutting speed when considering different steels. Roughing lathe tools of high-speed steel fail due to the continued rubbing or wearing action of the chips passing over the tool, and this finally results in a fairly sudden spalling of the nose. (Refer to Fig. 10.) As is well known, hardness as customarily determined is not a criterion of wear, and since wear causes the tools to fail,

hardness would not be expected to give a quantitative indication of tool life (or the cutting speed).

Apart from this, however, the tools and chips are both at high temperatures in rough turning, and it is known that the performance and properties of metals under such conditions are not indicated by, nor necessarily related to, tests at atmospheric temperatures.

While it is not yet possible to isolate all the important factors contributing to wear under any stated set of conditions, the problem is known to be complex and not tied up solely with the strength and hardness of the metals concerned. From this angle as well, it seems improbable that any general quantitative relations exist between hardness or other single mechanical tests and the cutting speed.

Since the tests previously described offered an exceptionally good opportunity to make comparisons between cutting speeds

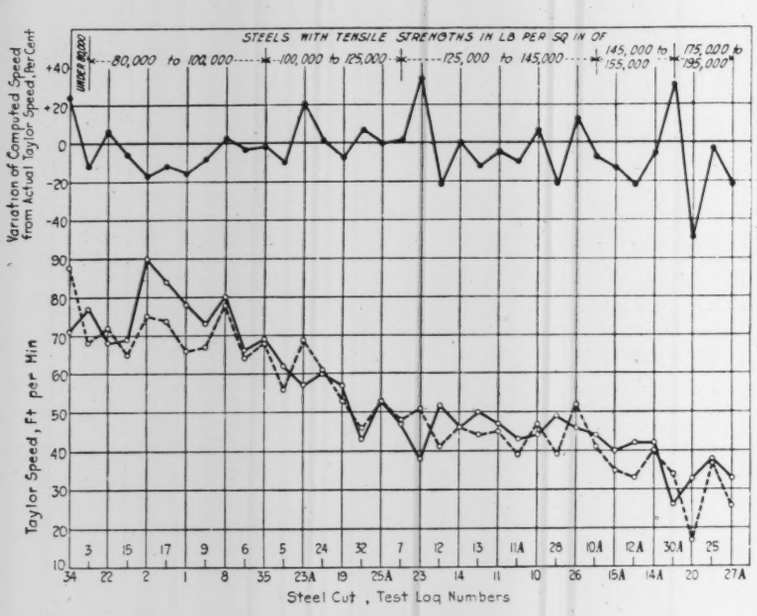
STEELS WITH TENSILE STRENGTHS IN LB PER SQ IN OF
UNDER 80,000
80,000 to 100,000
100,000 to 125,000
125,000 to 145,000
145,000 to 155,000
175,000 to 195,000
Variation of Computed Speed from Actual Taylor Speed, Per Cent
Taylor Speed, Ft per Min
Steel Cut, Test Log Numbers

FIG. 11 EXPERIMENTALLY DETERMINED CUTTING SPEEDS IN RELATION TO THE SPEEDS COMPUTED FROM THE RESULTS OF TENSION TESTS OF THE METAL CUT BY MEANS OF TAYLOR'S EQUATION

[Solid line denotes experimentally determined cutting speeds. Broken line denotes cutting speeds computed from the equation—

$$V = \frac{125\left(1 - \frac{215}{(15 + El)^2}\right)}{\sqrt{\frac{T.S.}{10{,}000} - 3 - 0.9}}$$

in which El = percentage of elongation in 2 in.; $T.S.$ = tensile strength in lb. per sq. in. The chemical compositions and tensile properties of the different test logs are given in Tables 2 and 3. The cutting speeds are for tool steel E, Table 1, when dry turning at 3/16 in. depth and a feed of 0.028 in. per revolution.]

and the mechanical properties of the steels cut, a complete set of hardness tests were made. The determinations of hardness were made on samples taken from the test logs at the starting and finishing diameters of the cutting tests, and only average values used for comparisons. In general, a number of measurements were made on each specimen as follows: two Brinell impressions, eight to ten Rockwell impressions with the diamond cone penetrator and a similar number with the steel ball, five readings on each of two scratches made with the Bierbaum scratch hardness tester, and two time-hardness and five or six scale-hardness readings with the Herbert pendulum tester. None of the hardness tests is a quantitative criterion of the cutting speed but some give a better general indication than others.[6] The scratch test in its present form appears to give absolutely no indication of the cutting speed and shows the widest scatter of points, but this is undoubtedly due in part to the susceptibility of the method to errors in measurement.

There does not seem to be much choice between the Brinell, Rockwell B scale, Shore, or Herbert time hardness from the standpoint of a correlation with cutting speed, but certain other factors give to the Brinell test the most favorable rating. The two separate Rockwell scales required for steels varying so widely in properties as those cut in the reported lathe tests are a decided disadvantage. The Shore scleroscope, as is well known, must be used with considerable care to secure consistent results, and the Herbert hardness tester is primarily a laboratory instrument whose readings depend largely upon the manipulative technique. Because of these features the Brinell test is at present considered the most useful of the group in giving a qualitative, but by no means a quantitative, indication of the cutting speed.

In general, the cutting speed for a fixed tool life increases with decrease in tensile strength, proportional limit, yield point, and breaking strength and increase in elongation and reduction of area, but on the whole there is a wide scatter of points for each of these factors.[6] The best general indication of the cutting speed is given by the tensile strength. Likewise, there is a smaller scatter in points representing elongations than in those representing the reduction of area, but the authors do not believe that these factors will ever be generally useful in the development of an accurate criterion of the cutting speed as they are too greatly influenced by variables which do not materially affect the cutting properties.

The cutting speed is in no way even generally related to the energy required to break the steel in tension, as represented by the area under the stress-strain curves. (For detailed data refer to Tables 3 and 5.)

Many combinations of mechanical test values were compared with the cutting speed, but in no case was an especially close correlation found for all of the steels cut. For example, there is given in Fig. 11 for a majority of the steels cut a comparison of the experimentally determined cutting speeds with those obtained from Equation [6] representing the empirical relations developed by Taylor. The computed cutting speeds are based entirely on the results of the tension tests, but while they clearly follow the variations observed in the experimental results, they do not closely check the numerical values except in a relatively few cases.

The ratio of Brinell hardness to tensile strength is not exactly the same for different steels or for one steel which has been heat-treated to show widely different degrees of hardness. On the basis that some function of both of these factors might tend to smooth out the variations observed in a correlation of tensile strength and cutting speed, comparisons were made with the product of the tensile strength and the tensile-strength–Brinell ratio. These comparisons did not in general give a better indication of cutting speed than the tensile strength alone.

The Brinell numbers in the foregoing comparisons may be replaced by Herbert time-hardness numbers without appreciably changing the scatter of points.

Tests were also made on an Amsler wear-testing machine in which metal specimens in the form of disks, 2 in. in diameter and 0.4 in. thick, are driven simultaneously at two different speeds in contact with each other. The two specimens, representing in this case respectively the hardened tool and the metal cut, rub over each other in much the same way as the chip passes over a lathe tool, although under very much lower pressures and temperatures. The results obtained were disappointing, for, although no quantitative relation was expected between the Amsler wear-test results and the cutting speed, there was a possibility, despite the wide difference in conditions in the two types of test, that the steels which had the highest cutting speeds might also lose weight the most rapidly in the wear test.

The most striking feature of the results[7] is the complexity of the relations governing the wear of the different steels, which makes it impossible to interpret results from the present Amsler test in terms of tool performance. As shown, the order of wear resistance may be reversed by relatively small changes in one variable such as the contact pressure.

COMPARISON OF HIGH-SPEED STEELS WITH AND WITHOUT COBALT

It has already been shown that when one high-speed steel has a

[6] Results of these tests are presented in tabular and graphical form in the complete paper.

[7] Summarized by curves in the complete paper.

higher Taylor speed than another in cutting relatively soft steel, it will show approximately the same superiority in feet per minute when cutting harder steels. (Refer to Fig. 7.) Under such conditions the percentage of increase in output, whether based on the rate at which metal may be removed or the amount of metal cut before the tools must be dressed, is greater the lower the cutting speed.

Since the cutting speeds which may be used decrease with increase in hardness of the steel cut and with increase in feed and depth of cut, it follows that the greatest gain from superior tools is made in cutting the hardest steels or in taking the heaviest cuts (large depths and feeds).

To illustrate the order of magnitude of these effects, tool steels E and I may be considered. While comparable in respect to their chemical compositions, as ordinarily determined, and their heat treatment, they differ by about 10 ft. per min. in Taylor speed when taking a $^3/_{16}$-in. cut at 0.028 in. feed. This represents a superiority in cutting speed of E over I of 10 per cent when cutting at 100 ft. per min. but a difference of 50 per cent when cutting at 20 ft. per min. When translated into conditions more nearly approximating practical service, for example, speeds which permit a 1-hour tool life, these differences become somewhat smaller numerically but are still of considerable magnitude, as will be evident from Fig. 12. It is therefore of interest to consider the differences in cutting speed of the several lots of high-speed steel used in this investigation and the reasons for the superiority of some in comparison with the others.

The three main factors which influence the performance of high-speed steels are: the quality of the tool steel, the heat treatment to which it is subjected, and its chemical composition.

The heat treatment of the tools was not varied in this investigation as this subject was quite fully covered for lathe roughing tools in a previous report (2). The selected heat treatments (reported in Table 1) represent those known to give the best combination of properties to each of the types of high-speed steel used, and this phase need not again be discussed in detail. The tests made in this investigation throw further light upon the two remaining factors which contribute largely to tool performance.

It is well known that two lots of tool steel containing practically identical proportions of carbon and special elements such as chromium, tungsten, vanadium, etc., may have appreciably different cutting speeds. Thus, when taking a cut $^3/_{16}$ in. deep at a feed of 0.028 in. per revolution, steel E has a cutting speed which, on the average, is about 10 ft. per min. higher than that of steel I. Similarly, tool steel G has a cutting speed which is 4 ft. per min. higher than that of steel E and about 14 ft. per min. higher than that of steel I. The superiority of steel K over I is about 6 ft. per min.

Steels G and K are so-called cobalt high-speed steels, and for reasons already discussed (2) were heated to somewhat higher temperatures for hardening than similar steels without cobalt. The first of these cobalt steels, G, is superior to the best of the high-tungsten steels, lot E, while the second, K, is somewhat inferior. However, both are superior to the high-tungsten steel I. While this confirms previous results to the effect that cobalt additions assist in improving the performance of roughing lathe tools, it is evident that any superiority from such a source may be completely counteracted by inferiority in quality, as, for example, in steel K.

The low-tungsten–high-vanadium steel H has a cutting speed which on the average, is about equal to that of the best high-tungsten steel E; at the same time steel H and the low-tungsten steel L are better than the high-tungsten steel I.

These comparisons indicate that the quality factor is more important than the modifications in chemical composition which are considered, but at the same time confirm the generally accepted fact that the addition of about 4 per cent cobalt to the customary 18 per cent tungsten high-speed steel, combined with a modification in heat treatment, tends to improve performance in roughing lathe tools.

It should, however, be recognized that the gains from superior quality of tool steel, cobalt additions, and modifications in heat treatments are greater the harder the steel cut or the heavier the feeds and cuts. For what may be called moderate service the differences found in the described tests are small.

Approximate Determination of the Power Required in Cutting Different Steels

The power required in cutting was determined in practically all of the lathe tests referred to in previous sections of this report. While indicating wattmeters were used in some of these tests, most of the results were obtained from ammeter and voltmeter readings which were taken at more or less regular intervals throughout the life of the lathe tools. Since the lathe was driven by a direct-current motor, the average of the product of these voltmeter and ammeter readings represents the average power required for cutting plus that required to turn the test log in the lathe. By subtracting from this value the average product of voltmeter and ammeter readings taken while the test log was turning freely in the lathe, both before and after each tool test, a numerical value is obtained which represents the average power required in cutting.

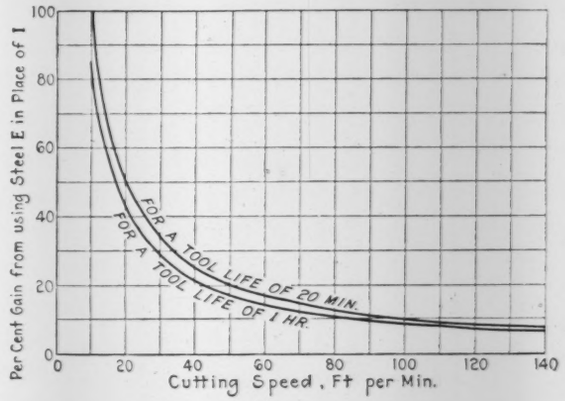

FIG. 12 PERCENTAGE OF GAIN RESULTING FROM USE OF STEEL "E" IN PLACE OF I AT DIFFERENT CUTTING SPEEDS

This method is not sufficiently sensitive for comparisons of individual tools, but served well for the purpose in view, namely, to secure data upon which to base computations of the power required for rough turning. The results are chiefly of interest in connection with power-transmission problems; but it should be recognized that only average values were obtained, and that the equipment available did not permit determination of the fluctuations or the maximum momentary power consumption, both of which must ordinarily be considered in power transmission. However, the experiments tie together the effects of variations in speed, feed, depth, and material cut upon the power required in cutting with the selected form and size of tool.

Within the limits of accuracy attained in the experiments there was no difference in the power required when cutting with the high-tungsten–cobalt, low-tungsten–high-vanadium, or high-tungsten–low-vanadium high-speed steels. Likewise there was no detectable difference in the power required in cutting steels of different compositions when these showed equal tensile strengths.

The results obtained in cutting $3^1/_2$ per cent nickel steel having a tensile strength close to 100,000 lb. per sq. in. are shown in Figs. 13 and 14. As can be seen, at constant feed and depth of cut the power is approximately proportional to the speed. Similarly at constant speed and feed it is approximately proportional to the depth of cut, and at constant speed and depth of cut approximately proportional to the feed.

If the constants of proportionality were consistent these relations could all be represented by the equation:

$$P = KFDS = KAS \quad [7]$$

in which K is a constant for the particular size and form of tool used and properties of the steel cut, F the feed, D the depth of cut, S the speed, and A ($= FD$) the area of cut.[8] A closer examination, however, shows that the constants are only roughly consistent

[8] That this equation gives approximate values for the power has previously been shown by Chas. Robbins in his paper on Power Required to Cut Metal, Trans. A.S.M.E., vol. 32 (1910), pp. 199–209.

with this equation. The constant K determined from Equation [7] for the determinations on 3.5 per cent nickel steel varied from 6.5 to 12.0, with an average of 8.3. Equation [7] can be relied upon to estimate the power roughly with a maximum error of about 40 per cent.

Equation [7] applies only to cutting the steel containing 0.3 per cent carbon and $3\frac{1}{2}$ per cent nickel when heat-treated to show a tensile strength of about 100,000 lb. per sq. in. To gain an idea of the variation in power when cutting harder or softer steels, the results obtained in cutting four different steels (at 0.028 in. feed, $\frac{3}{16}$ in. depth of cut) were plotted in Fig. 15. The ratio m of the slopes of the power-cutting speed lines to the slope for the nickel steel having about 100,000 lb. per sq. in. tensile strength

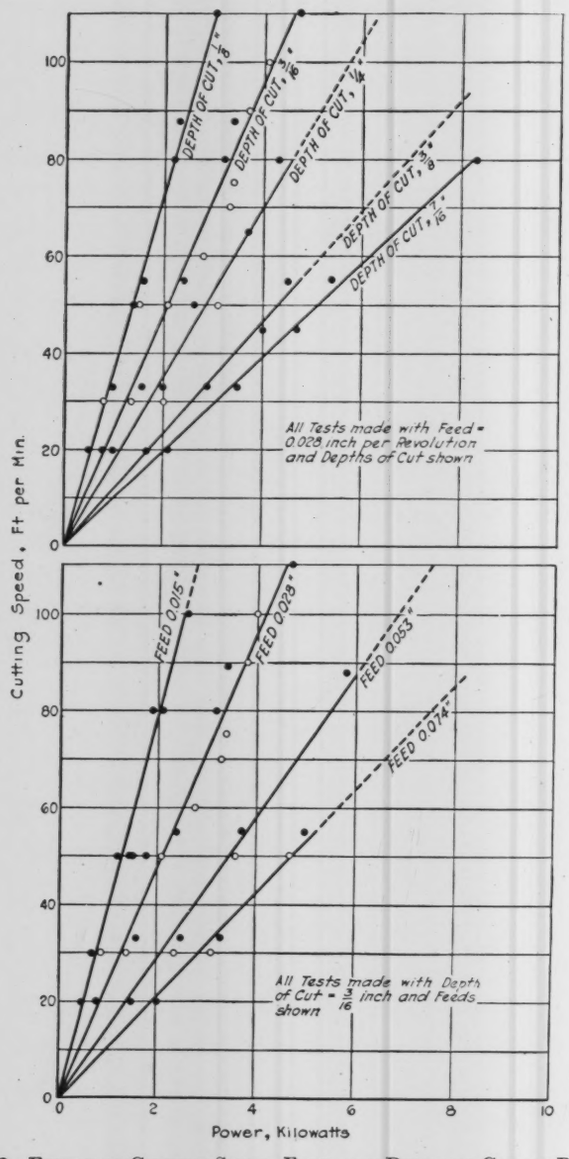
Cutting Speed, Ft per Min.
Power, Kilowatts
DEPTH OF CUT, 1/8"
DEPTH OF CUT, 3/16"
DEPTH OF CUT, 1/4"
DEPTH OF CUT, 3/8"
DEPTH OF CUT, 1/16"
All Tests made with Feed = 0.028 inch per Revolution and Depths of Cut shown
FEED 0.015"
FEED 0.028"
FEED 0.053"
FEED 0.074"
All Tests made with Depth of Cut = 3/16 inch and Feeds shown

FIG. 13 EFFECT OF CUTTING SPEED, FEED, AND DEPTH OF CUT ON POWER REQUIRED IN CUTTING $3\frac{1}{2}$ PER CENT NICKEL STEEL WITH TENSILE STRENGTH OF ABOUT 100,000 LB. PER SQ. IN.

[Tests made on test log 37, with tool steel K (represented by heavy dots) or P (represented by circles).]

were then plotted as ordinates, with the tensile strength as abscissas. The points lie close to the straight line.

$$m = 1 + \frac{4.5}{100{,}000}(T - 100{,}000) = \frac{4.5T - 350{,}000}{100{,}000} \quad \ldots [8]$$

where T is the tensile strength of the material cut. If the same variation with tensile strength be assumed to hold over the whole range of cutting conditions, we can write

$$P = mKAS = mKFDS \quad \ldots [9]$$

This shows that (Fig. 15) the power required in cutting steel having a tensile strength of about 175,000 lb. per sq. in. is roughly 35 per cent more than that used in cutting the $3\frac{1}{2}$ per cent nickel steel with a tensile strength of about 100,000 lb. per sq. in.; that in cutting steel with a tensile strength of 85,000 lb. per sq. in. is about 10 per cent less.

A graphical summary of the approximate relations between power, feed, depth, and speed, as represented by Equation [7]

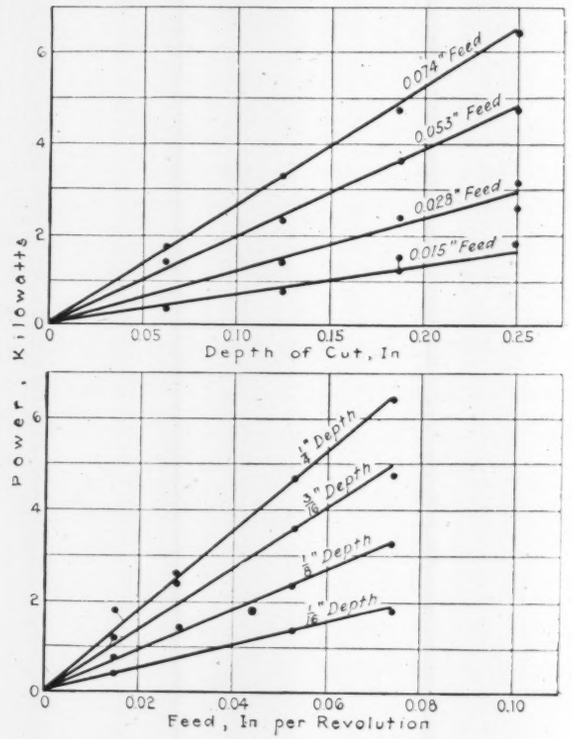

FIG. 14 EFFECT OF FEED AND DEPTH ON POWER REQUIRED IN CUTTING $3\frac{1}{2}$ PER CENT NICKEL STEEL HAVING A TENSILE STRENGTH OF ABOUT 100,000 LB. PER SQ. IN.

(All tests made dry at a cutting speed of 50 ft. per min. with high-speed steel K and selected size and form of tool used throughout investigation.)

is given in Fig. 16. This chart is divided into two parts; in the lower half, feed is the ordinate and depth of cut the abscissa, and the heavy curved lines represent combinations of feed and depth which give equal areas of cut and which likewise require equal power in cutting at any selected cutting speed. In the upper half of Fig. 16, speed is the ordinate and power the abscissa. The numerical values of the power required in cutting the $3\frac{1}{2}$ per cent nickel steel having a tensile strength of about 100,000 lb. per sq. in. (test log 37) at 50 ft. per min. are placed at the top of Fig. 16.

To find the power required in cutting at, say, 80 ft. per min. at 0.028 in. feed and 0.15 in. depth of cut, find the point in the lower half of the power chart, Fig. 16, representing the selected feed and depth, and project upward as shown by the arrows to the base line of the upper half of the chart. At this intersection project vertically to the 50-ft. speed line. Connect this point by a straight edge with the origin of the speed-power lines in the upper half of Fig. 16, and the point of intersection of this line and the chosen speed of 80 ft. per min. lies directly under the power required in cutting. By multiplying this value by the proper value of m given in Fig. 15, the power required in cutting harder or softer steels than the selected $3\frac{1}{2}$ per cent nickel steel can be obtained.

IMPROVEMENT IN TOOL PERFORMANCE FROM THE COOLING OF THE TOOLS WITH WATER OR OTHER LIQUIDS

It is, of course, well known that increased tool life results from the use of water or other coolants in rough turning, but the magnitude of these effects is known to vary, depending upon the cutting conditions. For example, by throwing a heavy stream of water directly upon the chip where it is being removed from the work,

in order to cool the tool, Taylor (4) obtained a gain in cutting speed of about 40 per cent with his original high-speed-steel tools. However, with his improved steels, the compositions of which more nearly resembled current commercial types, the gain in cutting speed was only about 15 per cent. But even this is important, for, as pointed out by Taylor, elaborate studies of the

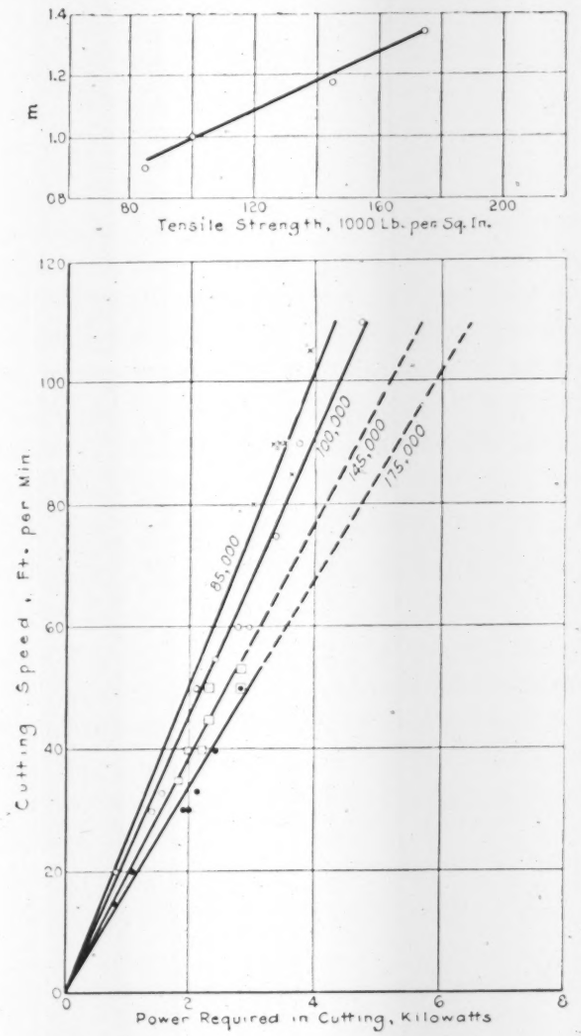

FIG. 15 EFFECT OF MATERIAL CUT ON POWER REQUIRED IN CUTTING STEELS OF DIFFERENT TENSILE STRENGTHS WITH SELECTED FORM AND SIZE OF TOOL

(Values of power given in Fig. 16 when cutting 3½ per cent nickel steel with a tensile strength of 100,000 lb. per sq. in. may be converted into the power required to cut harder or softer steels by multiplying by a material constant m whose values are given in upper part of chart.
Tests made dry with the selected form of tool described in the text at a feed of 0.028 in. per revolution and a depth of cut of 3/16 in.)

exact angles to which the tools should be ground resulted in many instances in "the very small gain in cutting speed amounting perhaps to from 2 to 5 per cent."

Several sets of experiments were made with high-tungsten–low-vanadium and high-tungsten–cobalt steel tools cooled with oil,[9] with an oil-water emulsion,[10] and with water to which about 1½ per cent by weight of soda was added to reduce corrosion of the machine-tool equipment. Care was taken to direct a copious stream of the chosen liquid upon the chip and tool, but the exact rate of flow was not measured except in tests on test log 38. A circulating system was installed on the test lathe in which the coolant was fed by a small pump through a half-inch nozzle so placed that the stream of liquid was thrown in the direction of the feed and down at an angle of about 45 deg. upon the top surface of the nose of the tool. By this method both the chip and the working portions of the tool were cooled.

The results summarized in Fig. 17 show that the gain in tool performance is somewhat greater with water than with the oil-water cutting compound, and likewise somewhat greater with the latter than with the paraffin oil. The effectiveness of these liquids in increasing tool life increases with the amount of water present and indicates that a large part of the benefits derived from their use is due to their cooling action rather than lubrication. Were lubrication largely responsible, oil would be expected to show an appreciable superiority, compared with water. This agrees with the results recently reported by Herbert (12), who has measured tool temperatures in rough turning. The lowest working temperatures were obtained with water, intermediate temperatures with

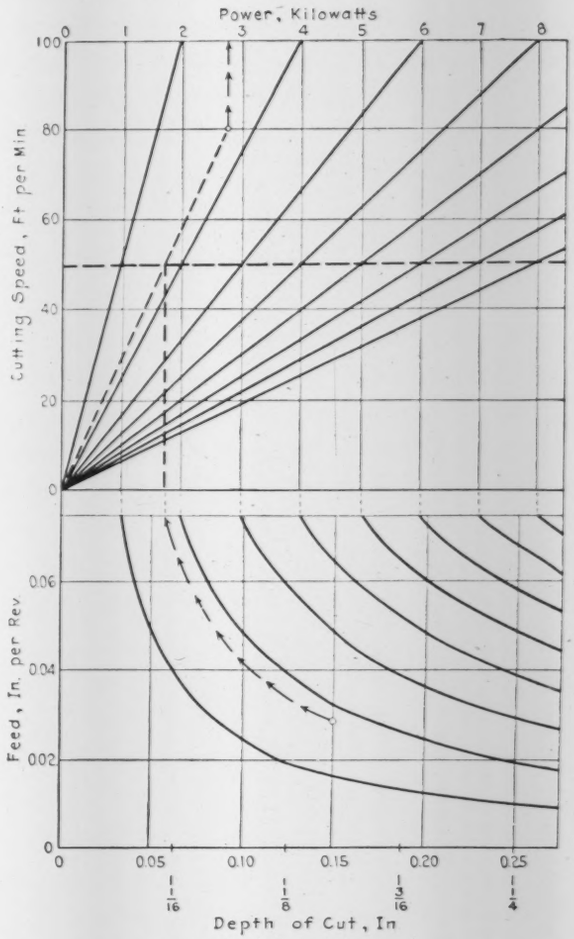

FIG. 16 POWER CHART

(This gives an approximate determination of power required in cutting, with selected size and form of tool at different speeds, feeds, and depths, 3½ per cent nickel steel with tensile strength of about 100,000 lb. per sq. in. Chart is drawn to represent Equation [7]. To obtain power required in cutting harder or softer steels under otherwise comparable conditions, multiply numerical values obtained from above chart by a material constant m whose values are given in Fig. 15.)

oil, and the highest working temperatures when cutting dry.

While there appear to be measurable differences in the effectiveness of the three liquids used, they are not large, as will be evident by examination of Fig. 17. This chart also shows that the equation representing the relation between the cutting speed and tool life in dry rough turning is applicable to wet turning, for when plotted to logarithmic coördinates the slope of the cutting-speed–endurance line in dry cutting is parallel to the lines representing tools cooled with water, the paraffin oil, or the emulsion. The lines are shifted to higher speeds by coolants, but their slopes are, for all practical purposes, the same.

The relatively small increase in cutting speed produced by the

[9] A paraffin oil was used, having a flash point of 320 deg. fahr., a fire point of 340 deg. fahr., specific gravity of 0.884, and a viscosity at 100 deg. fahr. of 75 Saybolt seconds, at 130 deg. fahr. of 53, and at 210 deg. fahr. of 34.

[10] The oil-water emulsion consisted of 1 part oil and 10 parts by volume of water. The oil consisted of a mixture of mineral oil and sulphonated saponifiable oils commercially known as soluble cutting oil. Sap. No. = 8.56; free organic acid (computed as oleic) = 1.46 per cent; sulphur = 0.53 per cent.

several coolants, amounting in the described experiments to from 5 to 15 per cent, is consistent with the relatively small improvement found by Taylor when cooling his best high-speed-steel tools.

Current types of high-speed steel for rough turning are unquestionably superior to and have a higher degree of what may be called "red-hardness" than Taylor's original high-speed-steel tools. Since the benefits derived from the use of water or other liquids appear to be due largely to reduction in working temperatures of the tools, it is not strange that a relatively small

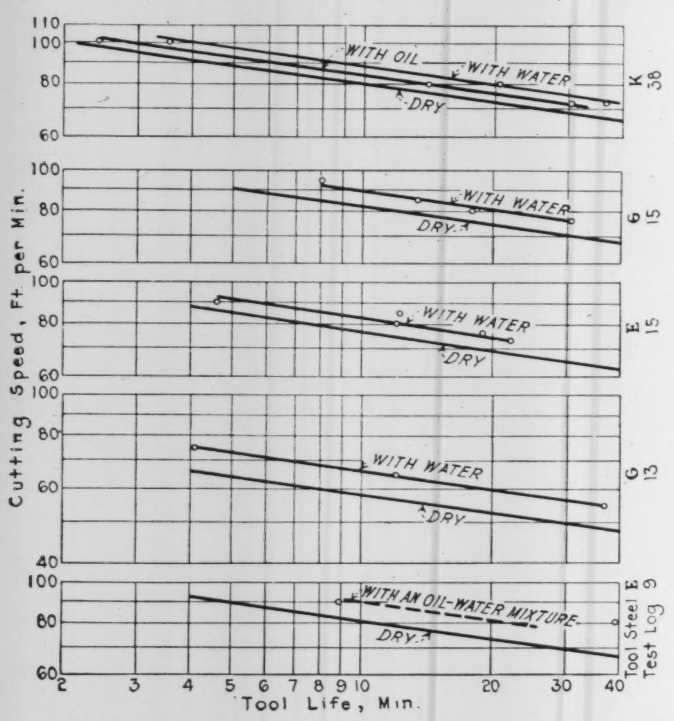

FIG. 17 EFFECT OF COOLANTS ON PERFORMANCE OF HIGH-SPEED LATHE TOOLS

(Tests were made at 3/16 in. depth of cut, 0.028 in. feed per revolution and selected form and size of tool used throughout investigation. For other details concerning conditions of experiments, refer to text.)

gain in cutting speed is shown in the experiments just described in comparison with the large gain reported by Taylor with the older types of steel. The latter were not so well fitted to withstand high operating temperatures and very severe service.

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Discussion

R. POLIAKOFF[1] contributed a written discussion in which he said that he thought it was of interest to see to what extent Taylor's recommendations had been accepted by the different steel manufacturers. According to Taylor, the best high-speed steel had to have a carbon content not above 0.68 per cent and not below 0.50, in order that the steel might be easily forgeable and not be brittle but sufficiently hard. The steels, as shown in Table 1, came well within Taylor's recommendation, but some European ones had a still lower carbon content. The European steels showed practically no manganese; the older high-speed steels had a manganese content up to 0.30 per cent. The steels used by the authors showed in some cases even a higher content. Taylor recommended that the manganese content should be as low as possible, because with a low manganese the steel became more ductile, less brittle, less liable to fire cracks, and more forgeable. It would seem that with regard to manganese the European manufacturers followed Taylor's recommendations more closely. As to silicon: Taylor's limit was "not over 0.15 per cent." The European steels were within this limit, the American steels overstepped it (with one exception). It would be interesting to learn from the authors their opinion as to the influence of such a larger silicon content on the durability of the tool, i.e., whether it affected it favorably or adversely. With a lower silicon content the tungsten content could also be decreased without affecting, to a certain extent, the durability. In the matter of chromium both American and practically all European steels failed to follow Taylor's recommendations, his figure being 5.5 to 6 per cent, particularly in the case of high-tungsten steels. For the relation between the life of the tool and cutting speed, Taylor's formula was

$$VT^{1/8} = \text{constant} \quad [1]$$

The formula of Ripper and Burley was

$$VT^{1/12} = \text{constant} \quad [2]$$

and the formula of the British Lathe Tools Research Committee was

$$VT^{1/7} = \text{constant} \quad [3]$$

In the authors' opinion the different values of the exponent in the formulas [1] and [3] were so close as to cause differences in computations not greater than 5 per cent—which was a quite permissible difference. To this Mr. Poliakoff wished to add that the difference would not be over 5 per cent for the lower limits of T (time) up to, say, 20 min., but would amount to 8 or 9 per cent of T values nearer the higher limits (90 min.), which was still not so bad. However, should we adopt the Ripper and Burley formula [2], with the exponent value of $1/12$, the difference in computations would amount to over 30 per cent, which was clearly not permissible. The authors, Mr. Poliakoff wrote, did not offer any explanation as to the reasons for the discrepancy in the values of the exponent in formula [1] on the one hand, and formulas [2] and [3] on the other; neither had he found any explanation of it in the original report of the Lathe Tools Research Committee. As his own explanation, he thought that the reason had to be looked for in the different values of the constants adopted or assigned by the different experimenters.

Carl G. Barth[2] wrote that if the negative results obtained in trying to establish definite relations between machinability hardness, of which there were two kinds, and the many other kinds of hardness of materials, could be made sufficiently known to dissuade the shop experimenter from wasting his time in this direction, then something practically useful would have been accomplished. There was not enough evidence in the experiments made to redetermine the speed-time relation to justify substituting the exponent $1/7$ for $1/8$ in the formula given in Taylor's On the Art of Cutting Metals[3] for that relation, namely, $V = c/T^{1/8}$.

When the experiments were made from which that formula has been deduced, the precautions taken to insure uniformity of both tool and material cut were so exceptional that much more than

[1] Mechanical Engineer, New York, N. Y. Mem. A.S.M.E.

[2] New Haven, Conn. Life Mem. A.S.M.E.

[3] Trans. A.S.M.E., vol. 28 (1907), p. 31.

appeared in this paper was necessary to justify this modification. For carbon-steel tools Mr. Taylor, personally and early, established the relations $V = c/T^{1/5}$; and as the later formula was based on experiments with the early type of Taylor-White high-speed tools, there was reason to believe that the further improved tools would actually call for a still smaller exponent rather than an intermediate one. For this, as stated in the paper, there had also been evidence put forth. On the strength of a few indications in Mr. Barth's experiments on cast iron at the works of Wm. Sellers and Co., the formula $V = c/T^{1/13}$ was adopted for the cast-iron slide rule, and it was interesting to note that this formula had the same exponent as that arrived at by Messrs. Ripper and Burley. Experimenters should follow Taylor's advice not to waste their efforts on power and pressure experiments under the false impression that such were of primary importance. The experiments under discussion were admitted to point to substantial agreement with the Taylor and Barth empirical formulas. Those, the authors implied, needed only to have their constants modified to suit both the slightly better tools of today and the various new steel alloys. Nevertheless, Mr. Barth took exception to the too simple form of the power formula $P = m\,KFDS$ in Equation [9]; for as the power was directly proportional to the tangential pressure on the tool, and as this varied with the feed raised to a power whose exponent was less than unity, so did also the power. This exponent had been indicated to be even as low as 0.7 in experiments made some forty years ago by Wilfred Lewis, which were found in Taylor's records and formulated for comparison with the results obtained from Mr. Barth's own experiments at the works of Wm. Sellers and Co. For cast iron the pressure varied even with an exponent of the depth of cut, though this exponent was much nearer to unity than that for the feed. The authors had paid some attention to the Taylor and Barth formula that was worked out to give some slight indication, by means of the tensile strength and percentage of elongation, of the machinability of various grades of carbon steels. It might be stated that the following much simpler formula covered the ground somewhat better:

$$V = C\,\frac{1 - \frac{7}{10 + E}}{S - 33{,}000}$$

instead of the original formula

$$V = C\,\frac{1 - \frac{215}{(15 + E)^2}}{\sqrt{\left(\frac{S}{10{,}000} - 3\right)} - 0.9}$$

in both of which

V = cutting speed for $^3/_{16}$ in. depth of cut, $^1/_{16}$ in. feed, 20 min. life
S = tensile strength, lb. per sq. in., for carbon steels only
E = elongation in 2-in. standard specimen
C = constant depending on the efficiency of tool used.

The authors had attempted to establish a relation of V with S, without at the same time taking into account the corresponding value E. The authors seemed to have the idea that Taylor conceded that he had found that the better high-speed tools did no more than 15 per cent better when cooled with water, even when used on the softer steels. Yet Taylor had died with the idea that a gain of some 35 per cent might be obtained when cutting soft grades of steel, on which the tools invariably "burned out," while on hard grades they wore off, as they also did when cutting cast iron. But a very heavy stream of water was necessary. At Bethlehem up to 3 gal. per min. was used. Besides, Mr. De Leeuw's remarkable experiments with high-speed milling cutters had demonstrated that the life of these when cutting low-carbon steels was merely a question of the quantity of cooling water supplied.

Thomas H. Wickenden[4] wrote that his company had investigated steels within the following S.A.E. steel specifications:

2340—$3^1/_2$ per cent nickel steel
3140—Chrome-nickel steel
4140—Chrome-molybdenum steel
5140—Chrome steel
6140—Chrome-vanadium steel

heat-treated to secure approximately an equal Brinell hardness of around 310. Samples of the various steels were turned with the same tool and the average result of 49 tests showed that machining the $3^1/_2$ per cent nickel steel consumed the least amount of power, while the chrome-molybdenum steel consumed the greatest amount—about 10 per cent more than the $3^1/_2$ per cent nickel steel. The carbon content of the chrome-molybdenum steel was toward the upper limit of the specifications, which might account for some of the difference, although the steels were so heat-treated that the tensile strengths were almost identical. On a great deal of production work the amount of finish left on forgings did not permit removing the metal at the maximum rate which the tool would stand. Hence it was often desirable to secure a compromise between the best possible finish and the amount of metal removed in a single machining operation. In cases of this kind the machining speeds to be used were often left to the judgment of the operator, who was apt to judge the machinability of the metal only by the type of finish he secured. Apparently there was a critical rate of metal removal which tended to produce a rough, torn finish, above or below which rate a smooth finish would be obtained. Thus when an 0.19 carbon, $3^1/_2$ per cent nickel steel normalized at 1600 deg. fahr. with a Brinell hardness of 166 was machined with a depth of cut of 0.045 in. and a feed of 0.030 in., a smooth finish was produced at a cutting speed of between 0 and 25 ft. per min.; a poor finish was produced between the speeds of 25 and 35 ft. per min. and a smooth finish was again produced at from 35 ft. to 110 ft. per min., the maximum speed tested. Cases occurred where the machinist, getting this rough finish, believed that he was operating at the maximum practical speed of machining, while if he had increased his cutting speed 5 or 10 ft. per min. he would have secured a smooth finish. It was further found that the cutting speed producing a rough finish changed when the depth of cut and feed relation were altered; that was, by using a depth of cut of 0.030 in. and a feed of 0.030 in. a poor finish was produced between the speeds of 0 and 60 ft. per min. and a smooth finish between 60 ft. and 285 ft. per min., which latter was the maximum speed tested. Heat-treating the material to a higher hardness was found to lower the cutting speed, producing a rough finish. At a Brinell hardness of 195 and a cut of 0.030 in. depth and 0.030 in. feed, a rough finish was produced at speeds between 0 and 45 ft. per min., while speeds of from 45 to 155 ft. per min. produced a smooth finish. When the steel was annealed, producing a Brinell hardness of 156, a cut of 0.030 in. depth and 0.030 in. feed produced a smooth finish at speeds of from 0 to 45 ft. per min., a rough finish at from 45 to 115 ft. per min., and a smooth finish again at from 115 to 285 ft. per min. It was also found that a sharper cutting angle on the tool lowered the speed at which a rough finish was produced.

H. W. Graham[5] stated that this study of rough turning was a valuable contribution to our all too elementary knowledge of the factors that governed rough turning. The problems associated with the light cutting and oftentimes delicate machining of the integral parts of such equipment as automobiles, motors, typewriters, etc., were of tremendous importance. The economic importance of light cuts and finish cuts appeared to overbalance that of rough turning. It was therefore to be hoped that the studies of the authors might be continued into the field of finish cuts.

A. L. De Leeuw[6] wrote that he was in complete agreement with the statement that a coolant increased materially the speed of the tool. In fact, two cases should be distinguished: first, when the tool was always embedded in the work, as a lathe tool; and second when it came out of the work, as a milling cutter. It was possible with a milling cutter to have unlimited speed. For instance, he had taken cuts as heavy as 5 in. wide and $^1/_4$ in. deep at a speed of 835 ft. per min., but such conditions could not be attempted when the tool was embedded in the work.

[4] The International Nickel Company, New York, N. Y.

[5] Chief Engineer, Jones & Laughlin Steel Corporation, Pittsburgh, Pa.

[6] Consulting Engineer, New York, N. Y. Mem. A.S.M.E.

A. L. Davis[7] also thought that the work described by the authors should be extended to the consideration of finishing tools. If this were done it would be valuable to conduct the experiments with a cutting time of not only 1 hour, but 4 or 5 hours as a base. This latter time was more nearly what practical men in the shops needed in their work. If a tool setter were required to operate half a dozen different machines he could only get around to them once or twice per shift, and the tools should last a little longer than this interval.

The authors, in reply to Mr. Barth's discussion, stated that the determination of power in their experiments had been wholly a secondary matter. They regarded the value of the exponent of T in Equation [2] as of minor importance. However, Mr. Taylor's On the Art of Cutting Metals had been searched very carefully without revealing as much direct experimental evidence to justify the exponent $^1/_8$ as the authors had found in their paper to indicate that the exponent $^1/_7$ would fit the results just as accurately. They had called attention to the fact that the constants for the straight-line relation between power and the various cutting variables were not entirely consistent, the variation being short of plus or minus 20 per cent. A closer determination of power would have given exponents which were not equal to 1. As stated in the paper, however, those exponents had been chosen for the reason that the authors had obtained a fair approximation which was believed to be consistent with the accuracy of the power measurements. Attention was also called to the fact that comparisons between the cutting speed and the various properties of material, such as hardness, combinations of tensile strength and ductility, etc., which were used or mentioned by Taylor or other experimenters, had been included only for the sake of completeness. The authors did not believe that a quantitative relation between the cutting speed and any one or two, or perhaps more, of the physical properties of the metal cut could ever be obtained. Such relations, however, were generally indicative in a given class of material, such as steel, as to what might be expected. For example, the cutting speed of a steel of Brinell hardness 400 was lower than for a steel of Brinell hardness 200.

Mr. Poliakoff had compared American and European tool steels. The authors believed that the amounts of silicon and manganese which were normally found in the American steels had only a minor effect on the durability of lathe roughing tools. This opinion was based on a large number of experiments in which various elements had been added to the standard compositions of high-speed steel.

The authors realized that finish cuts were perhaps of wider interest than roughing cuts, and experiments were now under way in that field. It was probable, however, that no one realized the size of the problem that was involved when it was recommended that the same things be done for finishing cuts in turning as had already been done for roughing cuts, even though the investigators had the genius of a Taylor and the facilities of wealthy companies back of them. Methods of test were available in rough turning which were not available in finish turning, and progress therefore had necessarily to be slow.

[7] Research Engineer, Scoville Manufacturing Co., Waterbury, Conn. Mem. A.S.M.E.

Designs Simplified by Electrical Means

MODERN motors and controllers have been developed so thoroughly and have proved so reliable in service that there is a strong and growing tendency to use electrical equipment for many purposes for which mechanical means were formerly employed. In designing machinery, it is frequently possible, by taking advantage of the electrical equipment now available, to reduce the number of shafts, bearings, gears, clutches, brakes, and other parts, thus making the machine simpler, cheaper, safer, easier to maintain, more convenient to control, and more productive.

It is not at all unusual for a number of motors to be used for driving one machine. It may be thought that the cost of the motors would be an important consideration in a case of this kind, but the cost of the motors is comparatively low, because of the large quantities in which they are manufactured. If the use of an extra motor results in the saving of only a very few gears and bearings, it will often be found that the motor costs less than the parts it replaces.

Probably the simplest method of obtaining changes in speed is by means of an adjustable-speed direct-current motor. A good illustration is a veneer lathe, the function of which is to shave a thin sheet of celluloid from a cylindrical block. It is highly desirable to keep the cutting speed constant as the diameter of the block is reduced. This is accomplished in a very simple manner by means of an adjustable-speed direct-current motor which drives the spindle through a worm and gear. The motor is controlled by a field rheostat, which is connected to the cross-slide, or knife-holder, by a rack and pinion, so that as the slide approaches the center it turns the rheostat, gradually increasing the speed of the motor and maintaining a uniform surface speed. As a result, the output of the machine is approximately twice what it would be if a constant-speed alternating-current motor were used.

It is interesting to note that the factory in which the veneer lathe mentioned in the preceding paragraph is used, was originally supplied with alternating current only. One reason for using alternating current was to minimize the transmission losses within the plant, the latter being spread over a large area. It was also felt originally that both fire hazard and the cost of maintenance would be greater with direct- than with alternating-current equipment. Later, however, it was found that in the case of many types of machinery these disadvantages were far outweighed by the advantages obtained from the use of direct-current equipment. A direct-current supply, in addition to the alternating-current supply, was therefore provided for driving certain machines, of which the one just described is an example. The use of direct-current adjustable-speed motors has simplified the machine, reduced the maintenance, and by permitting the use of the proper speeds to suit varying conditions, has increased the output decidedly. In the case of the factory just referred to, the question of fire hazard is unusually important because of the highly inflammable nature of the materials handled. This has not, however, prevented the use of direct current.

In considering the relative advantages of alternating and direct current, it is worthy of note that one of the larger automobile plants has been converted from alternating to direct current. Some idea of the magnitude of this undertaking may be obtained from the fact that some 30,000 direct-current motors were ordered at one time to replace alternating-current motors.

It is understood that one reason that direct-current motors were adopted was to make it possible to change the speed of the machines as often as desired by simply varying the amount of resistance inserted in series with the motor fields. With this provision for obtaining small changes in speed, it is easy to determine the use and proper speed for a given set of conditions and to change the speed as soon as conditions change.—H. L. Blood in *Machinery*, vol. 33, no. 7, March, 1927, pp. 481–483.

Introducing X-Rays into Industry

TODAY the microscope is a common tool in both research and control laboratories. In many organizations micrographic examination and micrographic record of representative samples are routine practice. Now other pioneers are introducing industry to X-rays. In one research program now being followed it has been decided to make an X-ray pattern of every specimen of which micrographic record is taken. These may disclose nothing valuable or they may unlock the door to invaluable information. It may not be an idle dream to think of the time when an X-ray pattern will be as common and as well understood where technical control prevails as is the micrograph today.

Where they can be used, X-rays furnish industry a powerful tool. X-ray equipment should not be installed until the adaptability of X-ray methods to the problem in hand has been demonstrated, and not then unless the benefits to be derived justify the cost. This would seem to make the tool unavailable to the organization with a small problem or a temporary difficulty. Fortunately, however, it is possible to evaluate any proposed use of X-rays without too great expense.—*Industrial and Engineering Chemistry*, March, 1927, p. 342.

The Industrial Application of Conveyor Systems

The Basic Law of Economics—General Types of Machines—Materials-Handling Equipment in the Laundry Industry—Effect on Growth of Laundry Industry

By C. A. BURTON,[1] NEW YORK, N. Y.

IN THE discussion of any branch of modern industry it is well to consider the relation of that branch to the industry as a whole. One must determine just how important a factor that particular branch is before one can intelligently discuss it and determine its effect upon manufacturing. Unless this is done one is likely to arrive at entirely erroneous conclusions, due to the over- or under-emphasis of the importance of the particular phase under discussion.

The author knows of no branch of industry that lends itself more readily to this over- or under-emphasis than materials handling. All who are engaged in this work know that there is a tendency to over-emphasize its importance. It is only natural, inasmuch as every one feels that his particular work is the most important of all, and perhaps it is fortunate that this is so, furnishing as it does an incentive to serious effort. It often leads one, however, into a very disastrous way of accepting a materials-handling system of itself as a cure for the ills of modern manufacturing.

The author remembers distinctly the remarks of Frank E. Moore, president of the Mathews Conveyor Company, at last year's Annual Meeting. He stressed particularly the danger of over selling the advantages of mechanical-handling equipment, and it can be said that every alert engineer and executive in this field is keenly alive to this danger. On the other side of the question one finds many plant superintendents and industrial engineers who consider materials-handling equipment as merely an adjunct to manufacturing and not a component part of it, looking to the materials-handling engineer only when a situation arises that places at some distance from each other two consecutive operations. Conveying machinery is then used to cure this purely local complaint, much as a person would use an application of linament for the alleviation of some ill that should be cured by getting at the very basis of the trouble.

The Basic Law of Economics

Between these two widely separated attitudes there must be and is some common ground, and it is with the idea of discovery of this common ground that the author undertakes a repetition of the basic law of economics having to do with the creation of value or utility in the raw product, which is nothing more or less than the problem of manufacturing. In order that any commodity may be of value to the consumer, it must have certain qualities, four of which stand out as most important.

First, it must have a utility of substance; in other words, it must be of the proper material. Second, it must have a utility of form; that is, it must be of the proper shape to be used. Third, it must have a utility of place; which means that it must be *where* needed. Fourth, it must have a utility of time; that is, it must be at hand *when* needed.

Just for illustration, apply this to a common commodity, say, coal. First, to be of value in warming a house, it must of course be coal. Second, it must be in pieces small enough to use in a furnace. Third, it must be actually in the furnace. Fourth, it must be there during cold weather when it is needed. Now, any operation that aids in producing these four conditions is vital and necessary. Let us then for a moment analyze these four qualities individually and see where the materials-handling industry fits in.

The utility of a substance is obviously the result of forces far beyond the control of man. Even if a chemist can form new substances, he is dependent upon the proper ingredients with which to work. The utility of form comes pretty close to expressing the whole problem of manufacturing, for finally all manufacturing consists of changing some raw material into a form in which it can be consumed. Materials-handling equipment certainly has little or nothing to do with the creation of these two qualities in the commodity. Obviously the third quality, or utility of place, is contributed almost entirely by materials-handling equipment, using the term in a broad sense to include railroads, steamships, trucks, cranes, conveyors, and even man's hand. This utility of place means not only the position of the commodity at the point of ultimate consumption but also its position at the proper place all through the process of manufacturing.

Now, it is obvious that materials-handling equipment in this narrow sense has to do with the placing of the commodity during its manufacture; that is, inside the plant. Other elements, such as railroads, trucks, etc., actually place the article at the point of ultimate consumption.

The above is all pretty clear, but how many of us consider materials-handling equipment as contributing to the fourth quality, namely, the utility of time? Here again the placing of the article at the point of consumption at the proper time is not meant, but the placing of it at the various manufacturing operations when it should be there. Assuming, and quite properly, that most identical operations take, or should take, an equal length of time, this means that units of manufacture should be fed to any operation regularly at intervals equal to the length of time required for the operation. As different operations vary in the time required to perform them, proper synchronization necessitates that there be different numbers of different machines, and one of the most valuable functions of continuous conveying machinery is the collection of units from one set of machines and the delivery of them to another set at the proper rate of speed for a second operation.

Types of Machines

There are two general types of machines. First, the continuous machine which operates like a sausage grinder; that is, performs its operations continuously and in such sequence that material may be fed in at one end at a given rate of speed and come out at the other end at the same rate. This is an ideal condition when viewed from the standpoint of efficient quantity production. The other type is an intermittent machine, which must be loaded, started, stopped, and unloaded, and which receives its material in large lots and discharges it in the same fashion. This type is the bane of the industrial engineer's existence and does more to interrupt smooth flow of production than any other thing in the plant, with the possible exception of the human element. The automatic continuous conveyor has in a good many industries done a great deal to translate that erratic gush of product into a smooth, even flow by providing a buffer storage space immediately before and after this type of operation.

This is largely theory, and the author knows that much of it will be doubted unless a concrete example is given.

Materials Handling in the Laundry Industry

In the last few years, probably the fastest-growing industry in this country has been the laundry industry. It has been neglected more or less by engineers, who have had in mind small hand laundries and have not realized its tremendous growth into real manufacturing establishments, great institutions with all the various subdivisions of work that characterize big industry. They create the utility of form, returning their patrons' clothing clean and ironed instead of dirty and wrinkled as it was received. The utility of time, in returning the clothing when it is wanted, also might be added, but some who have had sad experience might question this. At any rate, they must furnish dry, ironed clothing, and the machines for doing this are both varied and complicated.

The washers are cylinders about eight feet long and four

[1] Sales Engineer, Alvey Manufacturing Co., New York, N. Y.

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feet in diameter, rotating on horizontal axes. The extractors, huge bowls rotating on vertical axes, throw the water out of the clothing by centrifugal force. Tumblers are similar to washers, except that a blast of hot air is blown through them to dry the clothing. Flat-work ironers consist of a series of steam cylinders which iron all types of flat work and which are the only continuous machines employed, all the others being of what might be termed the periodic type.

To run through the operations briefly, the laundry is brought to the plant in delivery trucks, which discharge great lots of raw material. This is generally stored in extra trucks and fed in steady streams, usually by conveyors, to operators who subdivide the family bundle into the various divisions which require different treatment in washing and finishing. These operators are called classifiers or markers in the large laundries, and work is fed to them and taken from them by continuous belt conveyors which also feed the classified work to the washing machines and later the washed clothing to the extractors. As all these operations are of the intermittent type, the conveyors are designed so as to act as storage space and at the same time feed the work at the speed required. At the end of the extracting operation each unit is placed on the conveyor as removed from the extractor, and the result is a steady stream of boxes, each containing a family lot and all traveling to the flat-work ironers and other finishing machines, which are of a continuous nature. Following this process, the work travels on to the wrapping and delivery departments. One can readily appreciate that the smooth, even flow which is the ideal in all quantity production plants is thus insured as far as possible with the human element considered. The conveyors synchronize the movement of material with the machine capacities, and both set a sort of tempo which the operators find very hard to interrupt.

Effect on Growth of Industry

Such modern methods have had a great deal to do with the growth of the industry, since a great many peculiarities of the business tend to prevent a smooth, even flow of work through the plant. Not only do the bundles vary greatly in size, type, and class of work required, but they are received at the plant at one period of the day and a large percentage of the work is received in the early part of the week. This, together with the human elements involved, and the fact that most of the machinery is of the intermittent type, makes smoothing out of the production schedule of great importance and very difficult of attainment. The use of conveying machinery has aided materially in accomplishing this in many of the largest laundries of the country, and in every laundry where conveying equipment is used generally as a component part of the plant its most valuable feature, apart from direct labor saving, is the synchronizing and timing of flow of product through the plant, which is nothing more than the creation of time utility during the manufacturing process.

Discussion of Papers Presented at the Materials-Handling Session

TWO papers were presented at the session on materials handling during the Annual Meeting of the Society in December last. The first, Industry's Annual Tax for Materials Handling and Suggestions for its Elimination, by Harold V. Coes,[2] appeared in the Mid-November, 1926, issue of MECHANICAL ENGINEERING, page 1253. The second, The Industrial Application of Conveyor Systems, by C. A. Burton,[3] will be found on the page immediately preceding.

In presenting his paper in abstract, Mr. Coes referred briefly to some of his experiences in the early days of the Materials Handling Division and the reaction of his associates when he attempted to apply some of the theories and formulas advanced by leaders in the industry. In his paper, he said, he had tried to set up a general picture of what he believed to be the situation in industry as a whole, to challenge the imagination and stimulate further activity.

[2] Vice-President and General Manager, Belden Manufacturing Company, Chicago, Ill. Mem. A.S.M.E.

[3] Sales Engineer, Alvey Manufacturing Company, New York, N. Y.

Industry's Annual Tax for Materials Handling and Suggestions for Its Elimination

In throwing the paper open for discussion, the Chairman, James A. Shepard,[4] mentioned the fact that in many cases much of the cost of manufacture was buried in the payroll, and upon careful analysis of the total cost often presented an alarming picture, sometimes amounting to four-fifths of the cost. In many industries awaiting the application of materials-handling equipment, he explained, the savings would not be so apparent as, for example, in the steel mills or lumber mills, because of the comparatively small saving in each operation; when the total figure was considered, however, the real value of the equipment would be apparent.

V. N. Tobin[5] wished to know if in figuring the set-up cost of machines such as punch presses or automatics an overhead charge as well as the bare labor charge was figured.

Mr. Coes explained that this was contingent upon the accounting method; whether it set the cost up on the basis of the machine-hour rate or whether it was simply based on what might be termed the prime cost and then the general part of overhead, which was from three to five times as much as the direct labor in many instances, simply spread over the whole. It was certainly possible in most cases, he added, to determine the various items involved, and the overhead certainly should be taken into the calculations.

Mr. Tobin then remarked that if the overhead was included, the expense of manufacturing in small lots was materially increased.

That, according to Mr. Coes, indicated that the equipment was not being used in the most economical manner. Continuing, he explained that if a ten-ton press was used to perform the duties of a two-ton press, the work was not properly allocated to the equipment, although it might in some cases of emergency prove worth while.

In connection with estimating the length of time during which the materials-handling equipment must be paid for, Mr. Tobin wished to know the maximum time that should be allowed.

In answering, Mr. Coes said that the policy that had been adopted by his company was that they would approve any requisition for materials-handling equipment in which the invested capital was amortized in a period of two and one-half years. After the first lot of equipment was taken care of on that basis, they proceeded to the next step, where they might find that it would pay to install equipment that would be amortized in a period of five years.

He explained that one of the reasons why he limited the period to two and one-half years in the particular case of his company was that they owned one factory in Chicago and leased another, and plans were in hand for consolidating these plants. Therefore, when the entire factory was placed on one floor, some of the existing spiral and gravity conveyors, etc., might not be applicable in the new plant.

The policy adopted by Mr. Carnegie in building up the United States Steel Corporation, he said, was to scrap any piece of equipment and replace it by any new piece of equipment that could be amortized in a period of five years, which was practically a 20 per cent basis. He was known to have scrapped entire plants which had scarcely turned a wheel, and costing thousands of dollars in some cases, because new equipment came into use which indicated that its invested cost could be amortized in a period of five years.

The General Electric Company, according to Mr. Tobin, made a practice of making equipment at its Lynn, Mass., plant pay for itself within one year, or two years at the longest.

At this point the chairman stated that it had been found that the materials-handling formulas, which had been made to some extent the basis for Mr. Coes' paper, were applicable for comparative analysis throughout industry; therefore, if there were any doubt as to the economical sizes of lots or other conditions in a prescribed process of manufacturing, the use of the formulas as applied to the two conditions would give the most economical combination.

Max Sklovsky[6] inquired as to what change had taken place in five years in the ratio between the men employed for making deliveries from department to department or from machine to ma-

[4] Vice-President, Engineering, Economic Research, Shepard Electric Crane and Hoist Company, Montour Falls, N. Y. Mem. A.S.M.E.

[5] International Motor Co., Plainfield, N. J. Jun. A.S.M.E.

[6] Chief Engineer, Deere & Company, Moline, Ill., Mem. A.S.M.E.

chine as compared with the men who were employed on direct processes.

Mr. Coes replied that the record had not been kept in just that form. He assured his hearers, however, that the ratio was decreasing for the reason that, in the case of his company especially, most of the savings were made in the elimination of labor, so that the payroll was actually reduced.

With practically an equivalent production, taking the entire cost into account, the overhead and the direct payroll decreased about thirty-five cents on the dollar in a period of two years. This was not entirely brought about by materials handling, although it served to speed up the various operations.

Mr. Sklovsky then inquired if the purchase of equipment was denied if it did not indicate adequate returns, or if a chance was taken on its showing a return later when it came within closer range.

Mr. Coes replied that unless the general superintendent and the engineering staff could lay before the management the facts that the equipment which they recommended would amortize itself from savings, under the policy laid down, in a period of two and one-half years, recognition was denied.

Mr. Sklovsky then explained that he had found that over a period of a dozen years the returns for handling materials far exceeded the cost of any kind of a set-up, and that in many cases equipment for handling materials which had not shown an adequate return, or which showed no return, actually proved to be highly profitable. In other words, the returns were far greater indirectly than directly. He also stated that in his company's plant about 16 per cent of the men formerly were employed in making deliveries. This had gradually been reduced to 2.5 per cent, and there were hopes of reducing it to a one per cent basis.

P. F. Nydegger[7] related his experiences with electric trucks, both of the solid-platform type and the lifting type. A survey of the upkeep cost of these trucks showed that in certain departments it was four to five times as high as in other departments for handling practically the same load, and the departments showing up the best had good floors. Attempts were being made to bring down the high upkeep to a point nearer the lower upkeep, and he wished to know if such a thing were possible, and what the average upkeep cost was for a storage-battery truck of three tons capacity taken over a period of some years, running for eight to nine hours a day, operated by a fairly well-broken-in operator.

Mr. Coes felt that this could best be answered by a representative of the manufacturer. His experiences had absolutely paralleled those of Mr. Nydegger's. He had further observed that in certain places where insufficient aisle space had been provided, the rubber tires were badly cut. There was no question in his mind that the maintenance of both the hand- and power-operated trucks was dependent very largely upon the conditions of the floor, assuming that adequate instruction had been given to the operators and that their average intelligence was about the same.

He did not have the figures requested, but felt that they could be obtained if experiences in a number of plants could be matched.

The average upkeep figure of 24 electric trucks in Mr. Nydegger's plant, taking the high upkeep and the low upkeep together, ran around $5 or to $5.50 per week of 49½ hours. The peak, Mr. Nydegger said, was around $12, and the low mark a little below $3.

The Chairman thought that application to the manufacturers of trucks would probably develop the most reliable data available. He did not believe that the minimum could always be realized, owing to varying conditions throughout any plant, and the average perhaps would have to be accepted as the best available.

Regarding Mr. Coes' practice of refusing to pass a requisition for a piece of equipment that did not show a profit, he said that handling equipment sometimes had to be specified in groups, since one was not always able to make the conveying equipment hook up completely. Then the storage-battery truck would be essential to get out of the conveyor its full capacity, and in those cases an averaging of the team of equipment rather than segregating the estimate to a single view was desirable.

[7] Superintendent, Singer Manufacturing Company, Elizabethport, N. J. Mem. A.S.M.E.

There were many places in the materials handling system where Charles H. Bigelow[8] found it very difficult to formulate figures showing that apparatus applied or bought was going to make a saving in a certain time, yet, he said, often a greater saving than expected was the result. On the other hand, the maintainance proposition entered, and something which looked feasible might cost a great deal more to operate than one realized. As an example, he mentioned an industrial-truck operator who moved the material very quickly, but the truck was a wreck when he had finished with it. Another man did not move material quite so quickly, but the truck gave much longer service.

A fleet of industrial trucks was run up a sharp incline to the charging point at night. In the winter the incline was covered with sleet, so finally it was changed to the other end of the building. There was a saving, he said, but it was very hard to put it down in dollars and cents.

A railroad crossing had been found hard to keep in good repair. Finally the consent of the management to allow the laying of a concrete crossing was obtained. The result was a big saving, but again it could not be evaluated in dollars and cents.

The Chairman stated that that very problem had been anticipated, and it was hoped that within a measurable period there would be published the best obtainable data covering it. Regarding the question of better results than shown by the estimate, he said that that was a situation which perhaps accounted more than any other for the materials-handling formulas already mentioned. Until it became possible to pick up all of the factors or the major factors which influenced an installation and integrate them in the accounting, he explained, there could never be a true reflection of what would be found in operation. But, he added, with progress to the point where all of the factors that were pertinent in the estimate could be identified, the variant would be less and less.

J. C. Gillette[9] said that his company's problem of materials handling was tied up so thoroughly with production that it was very difficult to separate the handling costs. Their problem was one of taking up materials and putting them on some sort of a vehicle and then moving it down through the room with anywhere from ten to one hundred people performing different operations on the particular piece of goods going through. For that reason it had been almost impossible to make up any intelligent estimate of the savings. He wondered if Mr. Coes had taken that phase into consideration.

He then mentioned a plant manufacturing dry-cell batteries in which the operators pushed the trucks from one place to another. The output was 36,000 dry-cell batteries in a nine-hour day. A conveying system was installed, with the result that with the same floor space and approximately 6 per cent fewer operators, the capacity was increased to 65,000 dry cells per day. That was the result of two things: first, uniform pacing of work, and second, the fact that the operator did nothing but productive work.

He felt that eventually the greatest savings would result not from cutting down the move-men's work, but from confining operators to productive work entirely.

The procedure for the time being, Mr. Coes explained, referring again to his company, was to study methods which would reduce the manfacturing cycle, which of course meant increased turnover, goods produced with less work in process, and a greater use of the productive equipment, the productive capacity, and the productive floor space. They expected to make their savings through a reduction of the cost of the article, and they might know before they got through just how much the conveyor or other equipment contributed to it, but at the start it would probably be buried in the actual reduction of the manufacturing cycle.

Alfred Vaksdal[10] said that he was pleased to note the conservative figure of two and a one-half years, although he admitted that he had violated the rule several times, adding that there were many intangible savings, as well as intangible losses. He felt that sales engineers often overestimated the intangible savings as well as the savings themselves, and regretted that there were not more practical than theoretical engineers in the sales field.

[8] Plant Engineer, Spicer Manufacturing Company, South Plainfield, N. J. Mem. A.S.M.E.

[9] National Carbon Co., Inc., Cleveland, Ohio. Mem. A.S.M.E.

[10] Plant Engineer, Corning Glass Works, Corning, N. Y. Mem. A.S.M.E.

It was also his opinion that a good many plants were over-equipped rather than under-equipped.

Regarding electric trucks, he said that his company used about six of them and on all sorts of work, including the erection of steel for buildings and stacks, and moving heavy machinery. The heaviest maintenance charges resulted from broken frames. This was finally overcome by building an extra strong frame to withstand the shocks of rough yard operation. The cost was about $5 per week.

Although the equipment was supposed to reduce labor, his experience had been that the payroll did not go down.

F. E. Blake[11] wished to know if any relation had been established between the cost of an entirely new plant, the cost for land, building, and productive equipment, and the amount of capital investment warranted for materials-handling equipment for such a plant.

In reply, Mr. Coes stated that his company had made studies to find out just what they could afford to spend to modernize their present plant as compared with the estimated cost of production in a new plant, and the comparison showed that they could not afford to conveyorize the old plant to approach the results or the reduction in cost that could be obtained in a new plant, for the reason that the physical limitations in many plants, floor levels, ceiling heights, elevator locations, and the like, prevented a proper relationship of departments.

He did not believe that it would be possible to establish a relationship in percentage which would apply except in a given case. One would have to set up one's costs, and then determine how much the unit costs were to be reduced before proceeding further.

Referring again to the experiences of his company, Mr. Coes said that it had been necessary to completely rebuild floors in some cases in order to operate heavy storage-battery trucks; so to determine the amount they could afford to spend to approach the predetermine unit cost, it became a matter of plain mathematical calculation. They found that they could not afford to modernize the old plant, but would have to condemn it and consolidate with another.

Commenting further on the points raised by Mr. Blake's question, the Chairman said that if a new plant were built around a good materials-handling plan, much of the materials handling would be eliminated. Thus, after this had been reduced to a minimum, if a good materials-handling system were installed the problem would be satisfactorily solved.

He did not feel that the point where formulas would bridge the gap covered by competent engineering service would ever be reached.

THE INDUSTRIAL APPLICATION OF CONVEYOR SYSTEMS

In opening the discussion on Mr. Burton's paper, Chairman Shepard said that it brought into prominence a quality in materials handling which was not always given its proper valuation, namely, the so-called productive operations. Those which gave commodities their form might have a very important effect upon the quality of products. Materials handling, however, had no effect upon the quality of product, assuming that it was conducted in a way that did not result in violence or damage, hence it represented one of the most attractive opportunities for economy possible. One could eliminate materials handling and the product would be just as good as it was before, but it was impossible to eliminate anything which pertained to the forming of the product, or to expand it in many instances without its being reflected in a product of lower quality. Hence, while it might be true that a money valuation could not always be placed upon materials-handling projects, if in the same bill a comparatively large expenditure going into overhead as a result of materials-handling activities as compared with the productive ones were visualized, knowing that the one produced something worth having and that the other was a necessary evil but a waste so far as it might be eliminated and was not, one could at least make a shrewd guess as to what the proper course should be.

Mr. Sklovsky[6] offered figures on truck maintenance in which he showed that for 40 different units the average life was four years, with a normal annual charge of 25 per cent; 15 per cent going to maintenance and about 10 per cent for power, etc. He found, however, that any one of those units returned its value in from one to one and one-half years.

[11] State Engineer, Albany, N. Y. Mem. A.S.M.E.

He also mentioned instances where through rearrangement of equipment, materials were handled more adequately from machine to machine and the processing time increased to 40 per cent, where the former figure had been 30 per cent.

Commenting on the positioning of departments, as well as equipment within the departments, he said that his company had reduced in one year the total handling tonnage distances by 45 per cent. That did not add, however, a single handling device; it was a case of elimination of handling. He felt that in the application of handling devices a basic consideration was to what extent handling was required. First, handling should be eliminated as far as possible, and then what was left was best handled by mechanical devices.

Studies which Mr. Sklovsky's company had made showed that the handling of material, both between departments and between processes and between operations, amounted to 90 per cent of all the effort of men employed in production. In the case of the foundry industry, it was found that 96 per cent of all human effort went toward the handling of waste.

It was his contention that when it was recognized that manufacturing was largely a waste of materials-handling procedure, many of the problems would be solved in a far more ready manner than seemed possible at first glance.

His company had for a number of years applied various handling devices, such as overhead trolley systems, cranes, hand trucks, tractors, and conveyors of various kinds, and had found all of them very effective. The choice lay entirely upon the job at hand, he said. The company usually did not question the advisability of an expenditure in the direction of materials handling; it was approved without delay and without question, except as to the purpose for which it was to be used. No one was asked to set up a figure, for experience had indicated that any figures set up in advance would not predict the results that were obtainable later.

Ordinary freight elevators usually were not discussed, he said, but it had been found that their position was of utmost importance. He cited an instance in which the number of elevators was reduced from 16 to 4 with eminently better results and better service in every way, through proper location and by the use of proper types.

Conveying equipment, Mr. Sklovsky said, could not be studied independently, that was, independently of departments and of the general movement of materials. The shipping and incoming points had to be considered. There must be a general direction from the incoming side to the outgoing side of a plant. He mentioned a case where 40 per cent of the material, in passing from the primary departments to the point of shipping, traveled a total of 3100 ft. and through 11 different elevators, aside from other handling devices. Changes made in departments and in the location of departments had reduced the distance traveled to 600 ft. and required the use of but two elevators.

It might appear that the previous condition of the plant was ridiculous, but that was not the case, he explained. The company simply had not realized what the situation was. In most plants the situation was not much different; some were better and some worse, but with attention to the routing of material from department to department or from operation to operation, the more effective and the more profitable would manufacturing plants become.

Referring to Mr. Burton's doubts as to the possibility of evaluating time, McRae Parker[12] mentioned instances where this was easy to accomplish and where, in fact, the time was the essence of the proposition in hand.

One was in a department in a textile factory where, although the people were on piece work, it was found that by putting in conveying equipment the same group of operatives could do more work in the same time. In this case it was important that there be a larger return on the building investment, as the property had become very valuable, due to the commercial development in that particular territory. Another instance was in the handling of worsted goods after they had been dyed. The time that elapsed between the moment that the goods left the dye kettle and when they were dried was one of prime importance. By putting in a conveying system and doing away with the intermittent trucking, the time was very largely reduced.

In the first instance the time valuation could be figured out in

[12] Mechanical and Electrical Engineer, Cleveland Worsted Mills Company, Cleveland, Ohio. Mem. A.S.M.E.

dollars and cents in the overhead saved, while in the second instance it was apparent in the reduction of spoilage.

He took issue with the chairman on the matter of effect on quality, pointing out the fact that in the textile industry care in the handling of certain classes of goods, particularly what were known as creams, was very necessary. They must not be allowed to become soiled. In handling worsted tops, up to the time they became yarn, one must be careful in disturbing the fiber content. It had been the experience of his company that in establishing a certain conveying equipment the product had been rehandled less, and therefore the result of the conveying equipment had not only been to save labor, for which it was primarily put in, but had resulted in a better product during the processes.

The Chairman replied that this simply proved that handling did not contribute to the product, for if it was not handled it was better as a result.

To illustrate the effect of the presence of a mechanical element in a system largely dependent upon manual labor, Spencer Miller[13] described a scene on a banana dock in Costa Rica during the loading of a ship.

Although there was plenty of labor to be had, a belt conveyor was put in place on the dock. The bananas were brought to the dock on cars on a narrow-gage railway. Sufficient help was provided so that there was always one man waiting to place his stem of bananas on the belt. The result was a stem about every three feet. The man at the delivery end of the belt was obliged to take the stems as they came to him and deliver them to other helpers at slightly lower levels in the ship. The result was that the entire force was made to work at its maximum efficiency through the help of the conveyor, the driving power of the foreman being confined to the dock force only in seeing that the conveyor had its required number of stems per unit of time.

This experience, he explained, was of something like fifteen years previous, and he wished to know if any better or more economical system had been developed in the meantime.

J. W. Roe[14] also emphasized the value of the conveyor as a pace maker in connection with hand operations. He then asked several questions concerning the A.S.M.E. formulas for materials-handling calculations to clear up and confirm certain impressions he had received in using them in his work. These questions were answered to his apparent satisfaction by Chairman Shepard, who had presented the formulas in his paper[15] before the Spring Meeting of the Society in Milwaukee, Wis., May 18 to 21, 1925, through more careful explanation of certain passages of the paper. He urged those who had not read the paper carefully to do so, paying particular attention to the summary of the analysis, which would answer satisfactorily most of the questions likely to arise.

Professor Roe referred to the formulas as the soul of measurement. One must use one's judgment and base it on comparison, he said, but the difference between judgment and measurement was that all agreed to judge by the same standard in the same way. Even if it were not perfect but were a standardized method on which all would agree, we should be very, very much ahead.

Mr. Coes regretted the lack of tables comparable with the life tables of insurance companies which would be applicable to mechanical equipment, and mentioned the fact that in Europe one often found cars and locomotives in operation after 40 to 50, and even 60 years of service. In this country, however, the prevailing practice was to wear out the equipment as quickly as possible and get the maximum good out of it, and then replace it with new and more modern machinery.

J. C. Agry[16] wondered if it had occurred to any of those present that in many cases the interval of time required for completion of manufacture could be allied not only with production but with sales management. He referred to instances in shoe manufacturing where the interval of time of manufacture had been reduced from an average of 21 days in the plant to 5 days. This meant that from the production side one had the advantage of the reduction of capital tied up in process of manufacture, which was a tremendous item. Considered from the sales side, with the ability to turn raw materials into money, the difference between 5 and 21 days, or 16 days, was of considerable importance.

The Generation of Cycloidal Curves

By PAUL M. MUELLER,[1] HARTFORD, CONN.

AN EVER-INCREASING interest in and study of blowing devices for supercharging automotive internal-combustion engines has induced the author to prepare the present note dealing with the precise manufacture of one popular type. These devices at the present time fall into two classes, the centrifugal fan, either gear or turbine driven, and the so-called positive impeller type exemplified by the well-known Roots blower.

Of this latter type the generation of the cycloidal forms of the impellers will be discussed, using standard machine tools equipped with relatively inexpensive fixtures. The chief advantage obtaining with this method lies in the elimination of hand-filed templets and in the inherent accuracy obtainable from straight-line cutting edges and simple rotary motion.

The cycloidal curve of the impeller lobes used in the Roots type of blower is the trace of a point on the periphery of a generating circle which rolls without slippage on the pitch circle of the impeller. Thus it is possible to set a cutting point at this generating radius distant from the axis of the ram of a Fellows shaper and generate the tooth form required by rotating both cutter and blank simultaneously. However, a study of this method will show it to be relatively clumsy, difficult to measure, and very slow.

One special case of the cycloid curve is a straight line. It is the hypocycloid whose pitch radius is equal to the diameter of the generating circle. The straight line is the radius of the pitch circle.

If this be represented in metal, we have a cutting edge which is easily made and from which accurate measurements of set-up can be taken. Fig. 1 shows the basic method of generating the epicycloid. The blank is supported and rotated at M while the cutter is supported and rotated at C_o. The generating circle whose tracing point is O rolls on both pitch circle of radius R and cutter circle of radius $2r$. During rotation the point O follows both the epicycloid and hypocycloid C_o–O.

To complete the other flank of the impeller lobe it is necessary to have a second radial cutting edge separated from the first by an angular distance equal to $\frac{R}{2r}\gamma$, since the arc of the cutter gap O–O_1 must equal $R\gamma$, the arc thickness of the tooth at the pitch line.

The ratio of rotation must be the ratio of the circles which roll without slipping; thus

$$\text{Ratio of rotation} = \frac{R}{2r}$$

The dedendum of the cycloid may be generated with the same cutter in the same manner as shown in Fig. 2, with the exception that the cycloid is on negative metal, or, as it is usually expressed, is in the form of a templet.

Several points are worthy of note here:

1 The center distance is either the sum or difference of the pitch radius and the cutter radius.

[13] Chief Engineer, Lidgerwood Manufacturing Company, New York, N. Y. Mem. A.S.M.E.

[14] Professor of Industrial Engineering, New York University. Mem. A.S.M.E.

[1] Mgr., Sesamee Lock Div. Hartford Machine Screw Co. Assoc-Mem. A.S.M.E.

[15] Formulas for Computing the Economies of Labor-Saving Devices, by James A. Shepard and George E. Hagemann. Trans. A.S.M.E., vol. 47, 1925, pp. 525–551.

[16] The Lamson Company, Syracuse, N. Y.

2 The cutter radius is twice the generating-circle radius.

3 Only the addendum (or dedendum) may be generated in one set-up.

4 The cutter edge is tangent to the curve at the tracer point O and at 90 deg. to the line of action. In other words, the cutting edge is the pressure angle at any instant.

5 It follows from (4) that backlash may be introduced simply by placing the cutting edge parallel to its basic radial position and distant therefrom by one-half the amount of backlash desired.

6 The cutter may be used to generate any other cycloid whose generating circle and arc thickness are the same as those embodied in the cutter design.

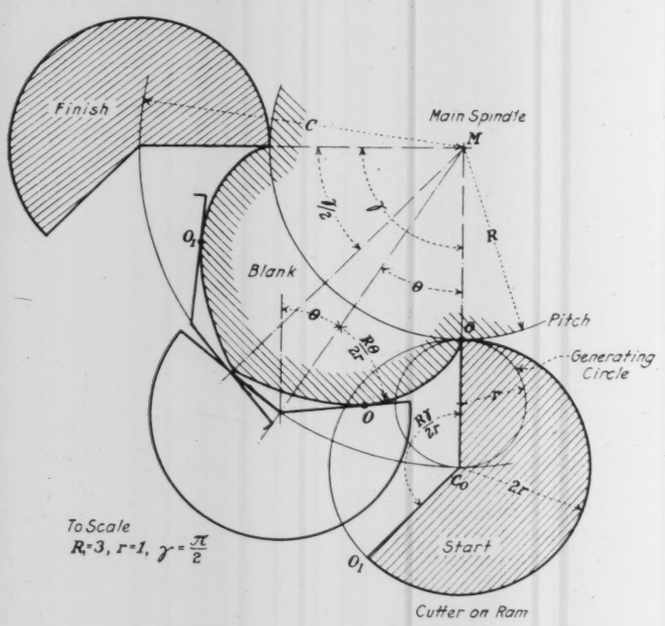


FIG. 1 BASIC METHOD OF GENERATING EPICYCLOID
(R = pitch radius; r = generating-circle radius; $2r$ = cutter radius; $C = R + 2r$ = center distance; O = generating point; $R/2r$ = ratio of rotation.)

In practice, where the axial length of the impellers is so great that a shaving chip from the ram action would be likely to tear the metal and spoil the finish, form milling cutters should be developed from templets about 1/2 in. thick. These cutters may be transferred from the templets nicely, using a contour cutter grinder.

It is preferable to generate the epicycloidal templet first. The blank should be sufficiently large so that after generation its appearance is similar to that of Fig. 3. The extra size makes it unnecessary to adjust the angular position closely, and the notches formed at the intersections of the epicycloids and the pitch circle will hold small cylinders from which location points may be established.

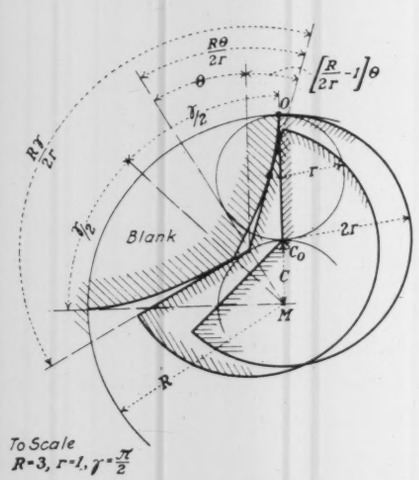


FIG. 2 GENERATING DEDENDUM OF CYCLOID
(R = pitch radius; r = generating-circle radius; $2r$ = cutter radius; $C = R - 2r$ = center distance; O = generating point; $R/2r$ = ratio of rotation.)

The cutting edge of the cutter is placed ahead of and parallel to the radius as shown at A, Fig. 4, so that the proper amount of backlash clearance will be removed from the templet. The small hole at the center and a plug furnish a convenient basis of measurement.

When the templet for the epicycloid is finished, the cutter may be reground with the edges below the basic radius. This will add backlash metal to the negative templet of Fig. 2, or will remove it from the impeller.

The templet should be made from a slightly larger blank in order to provide for notches to which measurements can be referred. Its appearance is shown in Fig. 5.

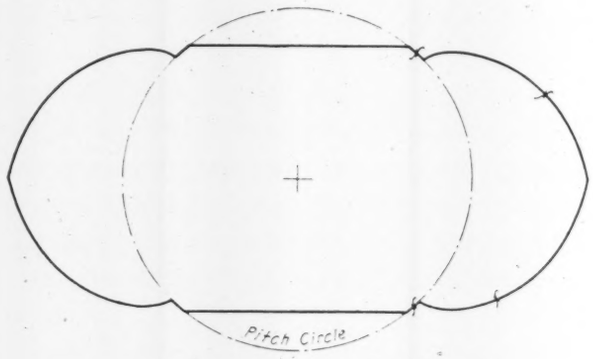


FIG. 3

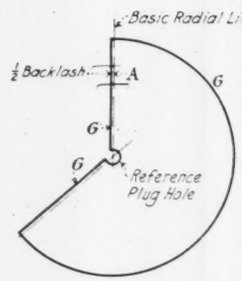


FIG. 4

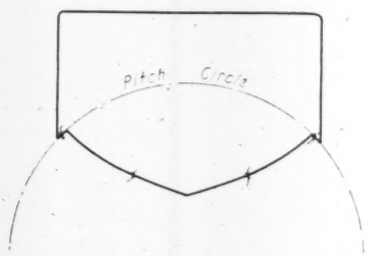


FIG. 5

FIG. 3 BLANK FOR EPICYCLOIDAL TEMPLET; FIG. 4 CUTTER WITH BACKLASH CLEARANCE; FIG. 5 TEMPLET BLANK WITH NOTCHES

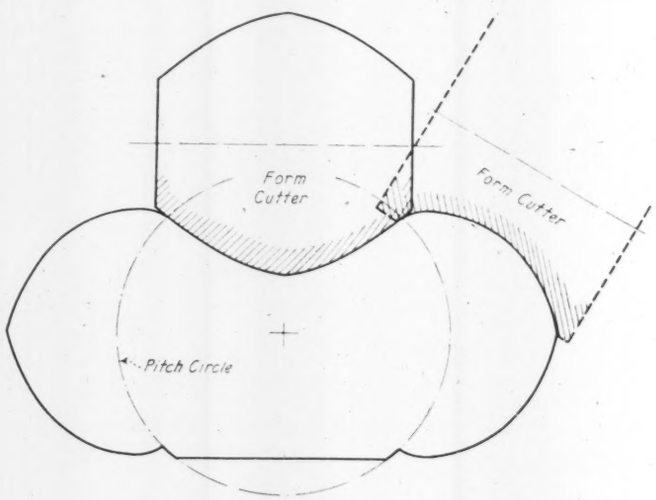


FIG. 6 COMPLETED MASTER TEMPLET AND OUTLINES OF FORM MILLING CUTTERS

A milling cutter is formed directly from this templet and then used to complete the master templet originally generated as shown in Fig. 3.

Fig. 6 shows the completed master templet together with outline drawings of the two form mills used to duplicate it in the work.

The above-described method of forming the templets is by no means limited to the Fellows generator. A little consideration will adapt it to gear generators of the Maag type, and it is even possible to use a milling machine only. Aside from exercising a little patience, nothing is necessary beyond the regular index centers and a single-bladed fly mill whose angle to the axis is adjustable.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

AERONAUTICS

The Evans Crash-Proof Tank

MAJ. H. H. EVANS, of London, is said to have developed a gelatinous compound which can be cast around an ordinary tank, forming a layer which acts both as a shock absorber and as a self-sealing gasoline container.

Recently Major Evans has constructed an experimental tank consisting of two tinned sheet-steel skins, one within the other, separated by a relatively thin layer of the gelatinous compound. A rectangular tank of this type, of ten gallons capacity, containing about seven gallons of water was taken up in an airplane at Stag Lane recently and was dropped overboard from a height of 300 ft.

Naturally the tank was very seriously deformed, but it remained perfectly free from leaks, and in no case have any of the joints in the tank seams given.

This particular tank is notably heavier than a normal unprotected tank, but this is inevitable in a tank of small capacity, where the total area of tank surface is large in relation to the cubic capacity. (*The Aeroplane*, vol. 32, no. 4, Jan. 26, 1927, p. 102, *d*)

The Ford Light Plane

THIS plane was designed by Otto Koppen of the Airplane Division of the Ford Motor Co., and is a small single-seater, low-wing monoplane, powered with a 35-hp. three-cylinder radial air-cooled Anzani engine driving a propeller approximately 5 ft. in diameter. The fuselage is a normal structure of wood longerons braced with steel wire and fabric-covered. The pilot's seat is so arranged that he sits up high and has an excellent view. The wing is of moderately thick section (Göttingen 387), has a span of 22 ft., and is attached to the lower longerons of the fuselage; it is provided with flaps extending along the entire trailing edge and divided at the fuselage; other than these flaps there are no wing-tip ailerons, the mechanism of the flaps being such as to enable either their differential operation as ailerons for lateral control or their linear operation as a means of altering the effective section, and therefore the lift of the wing. These flaps are worked by the control column in the same sense as this column operates the elevator, and hence no special effort is necessary on the part of the pilot to correct for any use made of the flap device.

In an endeavor to silence the engine the three exhausts from the cylinder are led out into an inverted U-shaped manifold, the outlets of which extend below the leading edge of the wing. At each of the outlets of this manifold a standard Ford-car exhaust silencer has been fitted, with the result that the exhaust noise is cut approximately in half. The plane leaves the ground after a very short run and has a good climb, indicating that there is plenty of reserve power. Brooks' handling of the machine is said to be perfect, exhibiting to the greatest possible extent its maneuverability. In landing, the machine has a low speed, due largely to the wing flaps, which are depressed, thus greatly increasing the lift of the wings. As soon as the tail is on the ground the friction brake becomes effective, with the result that the forward speed is checked within a few yards. On the ground, of course, the plane may be maneuvered with ease since there is no need to open the throttle in spurts to overcome the drag of the tail on the ground, and the machine can thus be taxied along steadily and with perfect directional control. In this way the plane has been driven down the street with ease. (*Aviation*, vol. 22, no. 3, Jan. 17, 1927, pp. 138–140, 1 fig., *d*)

The Beardmore Typhoon Engine

THIS is the first British inverted engine, in other respects very much like the Beardmore Cyclone, and has been installed on an old Avro Aldershot machine. It is a six-cylinder-in-line unit and develops between 800 and 900 hp. at approximately 1300 r.p.m. Its advantage is that like any six-cylinder-in-line engine it can be installed into a fuselage nose much narrower than will accommodate any V or radial type of engine of the same power. An inverted engine also permits of the nose projecting less above the airscrew axis than is possible with any cylinder-on-top type. The Typhoon therefore allows making the top deck to the fuselage both narrow and well sloped downward, and provides the designer an opportunity for obtaining the best possible view ahead and downward. The engine weighs approximately $2^1/_2$ lb. per hp., and a newer type with improved carburetors develops about 150 hp. more for slightly less total weight. It is said to be notably smooth running. At idling speeds with an occasional misfire the engine flicks visibly at the cylinder heads, but at all service speeds it runs dead steadily.

The fuel and oil consumption are said to total only 0.46 lb. per hp-hr., which is remarkably low (the average figure for a modern multi-cylinder type is 0.55 lb. per hp-hr.).

No details of construction have been released yet. From one of the photographs reproduced, however, it can be seen how simply the Typhoon may be mounted. No engine bearers are required, the crankcase itself being sufficiently rigid to dispense with these external aids. All that is necessary to carry the engine is a set of four steel tubes on each side running to the fixings provided on the crankcase. (*The Aeroplane*, vol. 32, no. 4, Jan. 26, 1927, pp. 100–102, 3 figs., *dA*)

Engines at the Tenth Aviation Show in Paris

WHILE no specially new types were shown at this show, a good deal of instructive material was revealed. Among other things, air-cooled motors with outputs as high as 600 hp. were shown, proving that motors of that size can be built without introducing too many complications and increasing the weight inordinately.

Water-cooled motors seemed to be lighter than air-cooled and, for example, the new Renault weighs only about 0.750 kg. (1.65 lb.) per hp. (dry). This very low weight has been achieved by increasing the output and arranging accessories in such a manner as to reduce the weight of transmission shafts, lightening crankcase and crankshaft, and, wherever possible, substituting forgings for castings. The above is not the lightest weight achieved, as the Fiat motor is a good deal lighter, but the Renault seems to have a longer life.

A table given in the original article shows the characteristics of the various motors. The larger motors are the most interesting. Of these, one (Fiat) has a nominal output of 900 hp. and an equivalent output of 812 hp., another (Breitfeld and Farman) has an equivalent output of 740 hp., and quite a number have outputs in excess of 450 hp. Superinduction appears to be employed only in the Breitfeld and Salmson motors, while reduction gears between motor and propeller appear in quite a number of machines. The compression ratio is mostly around 5.3 to 5.4, falling to 5 in the case of a few motors, chiefly British, and rising as high as 6 in the Lorraine and Panhard (French motors).

Of particular interest are the following: The Caffort engine was built for the particular purpose of being located within a fixed wing of a large plane. It consists of twelve horizontal cylinders opposed to each other in sets of six. This design permits making the crankcase very rigid, and the motor has a height of only 0.60 m. (23.6 in.). It develops 500 hp. at 2000 r.p.m., and is equipped with a reduction gear giving a propeller speed of 1060 r.p.m.

The Renault exhibit was remarkable because of the fact that the weight per horsepower of the motor has been reduced in the last three years without changing its relative dimensions, its general design, and without introducing any new departures such as

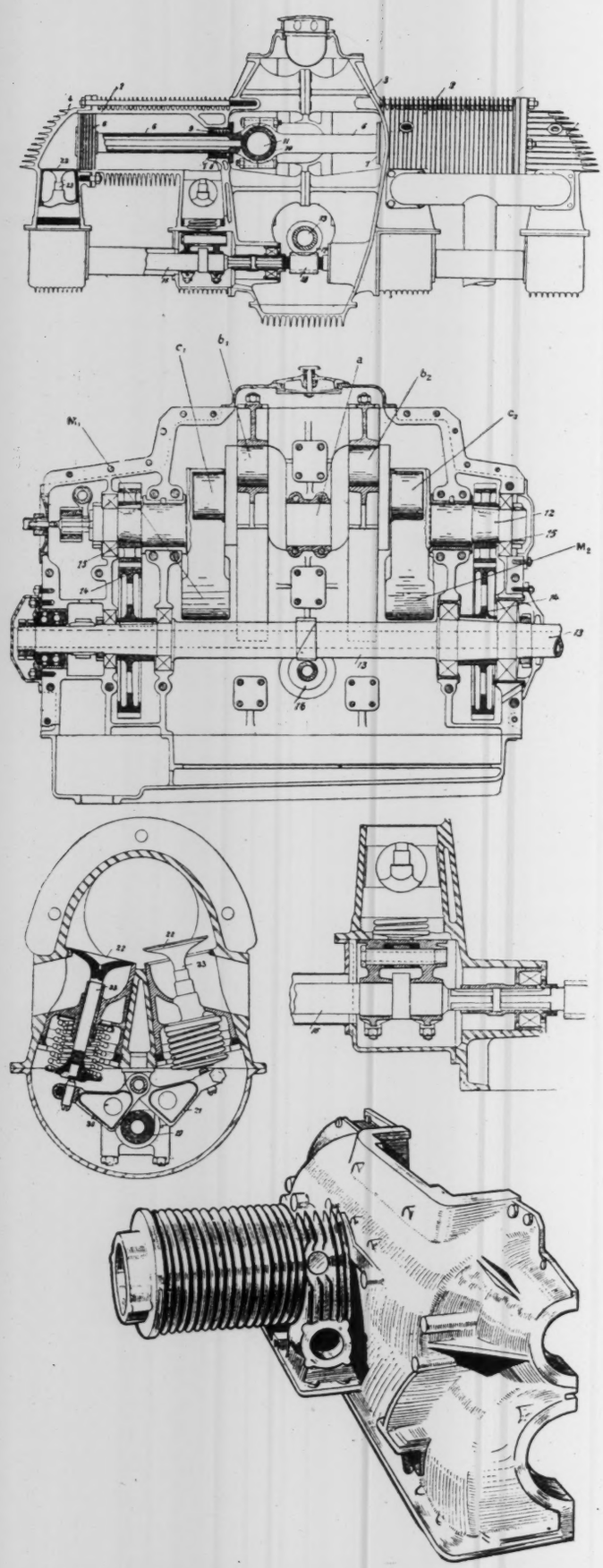


FIG. 1 POUIT AND GEORGES DOUBLE-ACTING AIRCRAFT ENGINE

the employment of unusual compression ratios, extra-light metals, or the like. In this case the weight was reduced simply by a number of refinements of design, making the job an unusually interesting one from an engineering point of view.

Among novel constructions the double-acting Pouit and Georges motor (Fig. 1) deserves particular attention. In this case a symmetrical crankshaft comprises five throws with the axes located in the same plane. The central throw a turns in the eye of a rigid connecting rod joining two pistons located at equal distances from this eye. The next two throws, b_1 and b_2, rotate into sliding plates so arranged that they can move in a vertical plane normal to the axis of the connecting rod; while the two outside throws c_1 and c_2, equally symmetrical, have their axes equidistant from the axis of the connecting-rod throw and the axis of the sliding throws and carry in their rotary movement two symmetrical semi-shafts each provided with a balanced flywheel and a pinion transmitting the movement at reduced speed to a jackshaft.

A camshaft parallel to the cylinders operates four pairs of valves located in four planes normal to the axis of the cylinders; a single cam operates two symmetrical valves (admission and exhaust). The displacements of the motor drive and the sliding pieces are sinusoidal, orthogonal, and phase-displaced to an extent of 90 deg.; the same applies to the accelerations which are composed of a balanced centrifugal resultant of the masses M_1 and M_2.

The problem of cooling has been solved in a very simple manner. The cylinders have no jackets. The pistons, connecting rods, and crankshaft are cooled by the lubricant which a special pump having a large output passes through an air-cooled radiator tank.

The construction of such a motor is very simple. Each cylinder is cast with half of the crankcase, which makes machining very simple. Furthermore, while this motor has the parts of a two-cylinder unit, it has an output of a four-cylinder one. Therefore it ought not to be very difficult to make a comparatively light engine. The designers so far, however, have paid more attention to the reliability of the machine than to its lightness.

The motor in operating condition with two magnetos and two carburetors weighs 120 kg. (264 lb.); the bore is 105 mm. (4.17 in.), the stroke 160 mm. (6.33 in.), the output 100 hp. at 220 r.p.m., and the reduction one-half. (*L'Aeronautique*, vol. 9, no. 92, Jan., 1927, pp. 11–21, illustrated, *d*)

AIR ENGINEERING

Explosions in Air Compressors of the Reciprocating Type

THE author points out that explosions of a rather disastrous character occur from time to time in high-speed reciprocating air compressors equipped with cooling by circulation of water around the cylinders. While this type of accident is fortunately infrequent, it is of interest to determine its causes and means of prevention. The author describes in this connection a number of the accidents which came under his observation and explains how such an explosion might occur. It is first of all necessary that a detonating mixture form at some point in the apparatus. The most important source of combustible element in such a mixture in this case is the lubricating oil, although explosions may be also due to accumulation of carbonaceous dust which may be of various origins. Moreover it is necessary that this mixture when it arrives at a proper composition be raised to a temperature sufficient to produce ignition, and this temperature is entirely covered by the flash point of the lubricating oil. Explosions of air compressors of this type, in the opinion of the author, must therefore be studied from the point of view of investigating the compression of the air and the causes which might produce an excessive heating of the gaseous medium, and next the lubrication of the compressors and the conditions under which detonating mixtures are apt to form.

Among the causes of excessive heating of the compressed air the author mentions poor circulation of water, high temperature of the air taken in, rise in compression ratio, defective valves, and poorly arranged automatic running at no load. In this latter connection he considers particularly compressors operated by alternating-current motors, which run at fairly constant speeds, and the various output regulators for the compressors. He mentions a French device by which the output of a compressor is governed by the tank pressure.

The most interesting part of the article is that dealing with

the influence of lubrication on explosion in compressors. In this connection the author arrives at the conclusion that in so far as the lubricating oil is concerned there will be no danger of explosions, provided (1) care is taken to use only a pure mineral oil of certain specified characteristics (given elsewhere in the original article); (2) the consumption of lubricant is reduced to a strict minimum; (3) the air taken into the compressor is carefully filtered so as to avoid the admission to the compressor cylinder of combustible matter which may be contained in the air; and (4) provided that at certain periods the cylinders, valves, and piping of the compressor are properly cleaned. (L. Lahoussay, Chief of Technical Services of the Coal Mines Committee of France, in *Revue de l'Industrie Minérale*, no. 146, Jan. 15, 1927, pp. 23–40, 11 figs., *p*)

ENGINEERING MATERIALS (See also Piping: Linings and Coverings for Water Pipes)

Calorex Glass and Vitaglass

THESE are two products controlled in England by Chance Bros. & Co., Ltd., of London. Both of them have been known for a considerable time in special applications.

Calorex has the property of admitting a large share of light but of passing only about a quarter of the heat radiation. It is therefore used in tropical and hot climates to admit sunshine into rooms without heating them excessively. As to Vitaglass, it is stated that it permits the passage of a large share of the so-called ultra-violet rays which are absorbed by ordinary glass. The article gives some data on transmission through these two kinds of glass and of some tests made with them. (*American Glass Review*, vol. 46, no. 15, Jan. 8, 1927, pp. 27–28, 2 figs., *d*)

Influence of Compression on the Brittleness of Steel

WITH a view to determining the influence of compression on the brittleness of steel, the author made a number of tests on bars of square section [32 mm. (1.259 in.) × 32 mm.] forged from the same billet and with the same carbon content (0.80). These bars were divided into three groups and differently heat treated. From the tests it would appear that as long as the load on the bar does not attain a certain critical value, the resilience of the metal does not seem to be materially affected by a previous compression, but beginning with that critical value the resilience falls off very suddenly. This critical value varies with the previous treatment of the bar, the figures being given in the original article. Because of this the author believes that attention should be called to the brittleness limit in compression. (P. Dejean in *Comptes Rendus des Séances de l'Académie des Sciences*, vol. 184, no. 4, Jan., 1924, 1927, pp. 188–189, *e*)

The Expansion Coefficient of Cast-Iron Pipe

AN UNDERGROUND steam line made up of 8-in. DeLavaud centrifugal cast-iron pipe with bronze welded joints was laid during October and November of last year by the United States Cast Iron Pipe and Foundry Co. in their plant at Burlington, N. J. Bronze welding of cast-iron pipe for this service was adopted because several such installations in the various plants of the company had shown this type of construction to be perfectly satisfactory.

As this line is supported on rollers and moves freely with temperature changes, a test was made to determine the free expansion and contraction of a bronze-welded cast-iron line and the linear coefficient of expansion of DeLavaud pipe. Prior to this investigation there were almost no data available on this subject. A definite figure on the coefficient of expansion is especially desirable in connection with the experiments, and investigations are now being conducted in the Burlington plant on the movement and stresses in buried bronze-welded cast-iron gas lines, since with these data it is possible to compare the theoretical movement with the actual measurements in restrained lines with changes in temperature.

The results of the tests are given in the original article and show that the average coefficient of expansion for DeLavaud pipe is 0.0000063. It is claimed that the deterninations of all the data with the exception of temperatures were made to within an accuracy of ½ of 1 per cent. (T. W. Greene, Engr., Linde Air Products Co. and Edward Hering, Asst. Engr., U. S. Cast Iron Pipe and Foundry Co., Burlington, N. J., in *Gas Age-Record*, vol. 59, no. 6, Feb. 5, 1927, pp. 187–188 and 196, 5 figs., *e*)

FOUNDRY

The "Still Casting" of Metals

DESCRIPTION of the so-called Durville process developed by the author and which is chiefly applicable to the casting of aluminum alloys. Various considerations in the paper show that such alloys must be poured with a minimum of agitation, which has been accomplished by the new method techically known in France as the "still casting" process (*coulée tranquille*).

There are three ways of "still casting:" by die casting, by employing the tilting process, and by bottom pouring. In the tilting process molten metal is first poured into the ladle and there cleansed of any dirt which has been produced by this pouring. The molten metal is then transferred to the ingot mold with a minimum of disturbance by tilting the whole system in a vertical plane. The process has been successfully developed in France for pouring aluminum bronzes and is now being introduced into this country. Its disadvantages are that it requires costly machinery, double pouring, and a certain difficulty in greasing the ingot molds. Its advantages are chiefly in the reduction of the number of skilled laborers, and the almost perfect surface of the ingot.

In bottom casting the metal is introduced into the mold with the minimum of agitation by means of a gate which is built up to its full height during the pouring operation. At all times it is at a very short height of fall, which prevents mixing in the dross caused by the wrinkles of alumina film. This method permits the casting of very large sizes for molding as well as ingot casting, and at the same time retains the advantages of greasing the ingot molds. (P. H. G. Durville, Constructing Metallurgist, Paris, France, in *Paper No. 1651-E of The American Institute of Mining and Metallurgical Engineers*, abstracted from preprint, 6 pp., *d*)

FUELS AND FIRING (See also Special Processes: Artificial Fertilizers and Liquid Fuels, and Bowie-Gavin Process for Cracking Heavy Oils; Internal-Combustion Engines: Fuels for Producer-Gas-Driven Trucks)

Fusibility of Coal Ash as Related to Clinker Formation

THIS investigation was undertaken at the request of the Committee on Coal and Coke of the American Society for Testing Materials, and was carried out at the Pittsburgh Experiment Station of the U. S. Bureau of Mines.

Seven coals, having ash-fusion temperatures ranging from 2070 to 2930 deg. fahr. were selected for comparative burning tests in a specially designed hand-fired furnace with a circular grate 20 in. in diameter and water-cooled iron walls. The furnace was so arranged that the air supply could be accurately controlled and measured; likewise temperatures could be observed at various points in the fuel bed. Tests were made at 20, 30, and 60 lb. of coal burned per sq. ft. of grate area per hour, and in certain tests the fuel bed was occasionally stirred. Observations on clinker formation were made during the tests, and after completion the percentage of ash fused into clinker was determined. These observations and determinations were then compared with the fusibility of the average ash of the coal fired and also with the fusibility of the intrinsic ash of the coal. The inherent intrinsic ash is that which is intimately mixed with the coal substance and which can be removed by coal-washing processes.

The first part of the investigation comprises a laboratory study of the nature, distribution, and fusibility of the ash of seven coals, and the second part is a study of ash-bed refuse produced by burning coal.

Some of the conclusions arrived at in the first part of the investigation are as follows:

Float-and-sink tests were made with the coals, after they had been crushed to pass a 20-mesh sieve, in a solution of benzol and carbon tetrachloride of 1.35 specific gravity. The float portions ranged from 65.6 to 87.2 per cent; they contained from 2.5 to

4.3 per cent ash, and the sink portions from 16.0 to 35.9 per cent ash.

Sulphur forms were determined in the original coals and in the float-and-sink portions. The sink portions contained more pyritic sulphur than the float portions.

Analysis of the ashes of the original coals and the float-and-sink portions showed that, with one exception, the ashes of the sink portions are higher in iron than the ashes of the original coals or those of the float portions. The alumina contents of the ashes of the float portions were higher than those of the ashes of the sink portions. The relative silica content of the ashes of the float-and-sink portions varied with the different coals.

The fusibility of the ashes of the sink portions was more like that of the ashes of the original coals than was the fusibility of the ashes of the float portions. In case of the two coals with the most refractory ashes, the ashes of the float portions were lower in fusibility than those of the original coals or the sink portions. The other five coals gave float portions having more refractory ashes than the ashes of original coals or those of the sink portions.

Part 2 discusses among other things practical methods of burning coal and the factors affecting the formation of residue. The clinkers formed in these tests were carefully examined, and an attempt was made to define their common properties; these are listed in a table in the original article, which, however, is too extensive to be reproduced here.

Suggestion is made of possible methods of measuring coal troublesomeness of clinker and determining the order of the for clinker troublesomeness.

Part 3 of the paper is devoted to the subject of coördination of clinker formation obtained by burning coals with the fusion and chemical analysis of the coal ashes.

The following conclusions are arrived at:

The average quantity of clinker formation relative to the total ash in the coal and also the size of the clinker pieces seems to have a fairly definite relation to the softening of the coal ash as determined by the standard gas-furnace method.

The relation is better expressed by using the softening temperature than it is by that of the initial or fluid temperatures.

No better relation can be obtained from the softening temperatures of the ash of the float-and-sink portions of the coal separated by fine grinding and using a liquid of 1.35 specific gravity.

The clinker formation does not increase materially until the softening temperature of the coal ash is below 2600 deg. fahr. (W. A. Selvig, Associate Chemist, and P. Nicholls, Fuel Engineer, U. S. Bureau of Mines; and W. L. Gardner and W. E. Muntz, Research Fellows, Carnegie Institute of Technology; with introduction by E. B. Ricketts (Mem. A.S.M.E.), in *Bulletin No. 29, Mining and Metallurgical Investigations* under the auspices of Carnegie Institute of Technology, U. S. Bureau of Mines and Mining and Metallurgical Advisory Boards, pp. vi–vii and 1–64, 11 figs., *epA*)

The Domestic Oil Burner

INVESTIGATIONS of oil burners for home heating by the United States Department of Agriculture indicate that they are well suited to the requirements of many home owners on account of their convenience and ease of heat control if, to obtain these advantages, the prospective purchaser is willing to pay the cost of the change and possibly an increased operating cost. Before deciding whether a change to oil burning is desirable there should be a thorough understanding of the adaptability of the present heating plant to oil burning, of the operating characteristics of different types of oil burners, and of installation and operation costs.

Fuel for oil burners is derived from crude oil after other products have been extracted and is sold in various grades, the proper grade for use in any case being determined by the type of burner in which it is to be used. Great ingenuity has been shown in developing apparatus to burn these oil fuels. One general type, the vaporizing type, secures combustion by allowing the oil to drop on a hot plate by which it is vaporized, after which it is mixed with the air in the chamber and burned. The plate must be heated to start operation, and in general these burners are not equipped with automatic control. They require a light oil which costs somewhat more per unit of heat than the heavier grades.

The atomizing types have a motor and other mechanical devices for atomizing the oil and mixing it with air before delivery to the combustion chamber. They are generally equipped with full automatic control, are less exacting as to the type of fuel required, and are less given to smoking and sooting because of better combustion.

Several types of burners now on the market afford good combustion of oil fuels, and tests have shown that there is no material difference in the efficiency of the better makes. Any burner which will burn the fuel without giving off soot or smoke and does not require a great excess of air may be considered as satisfactory with regard to combustion.

Oil burners are being applied to all of the types of heating plants commonly used for home heating. If the present plant, when burning coal, does not give sufficient heat, very probably an oil burner will not improve this condition. In general, warm-air heaters are less suited to oil-burner installations than are hot-water or steam plants, principally for the same reason that coal-burning warm-furnaces are sometimes objectionable, namely, that leaks develop between the firepot and warm-air passages which permit gases to permeate the house. The condition is somewhat aggravated in the case of an oil-burner installation because of the greater intensity of the flame and the alternate heating and cooling as the burner is turned on and off. However, there are warm-air furnaces of such design and construction that the likelihood of gas leakage is practically eliminated; and many such installations are giving entirely satisfactory service.

Safety is of paramount importance in any device to be used in the home, and, regardless of any advantages claimed, no one would be justified in installing a burner that is not reasonably safe. The Underwriters' Laboratories have tested and listed many of the burners now manufactured as complying with certain standards of minimum hazard. Burners that have been so tested bear a mark indicating the fact. However, the absence of such marking does not necessarily mean that a burner does not comply with the requirements of the Underwriters' Laboratories, since there are on the market a number which have been submitted for test or which are now on the waiting list. (Arthur H. Senner, Asst. M.E., Division of Agricultural Engineering, Bureau of Public Roads, in *Department Circular No. 405, U. S. Dept. of Agriculture*, Jan., 1927, 30 pp., 23 figs., *dc*)

HYDRAULIC ENGINEERING

The Hydraulic Jump as a Mixing Device

THE "hydraulic jump" may be defined as that phenomenon in which a part of the kinetic energy of a stream of water flowing in an open channel, at less than the critical depth, is converted into potential energy in the attempted turbulent passage from the lower to the upper alternative flow level. These alternative levels are the only two possible levels for steady flow under a given energy condition; and the critical depth is that depth at which the alternative levels coincide. For any given channel section and given quantity of water the critical depth is a constant, and represents the minimum amount of energy for that particular set of conditions. In other words, the critical depth for any depth discharge per unit width is that depth for which the value of the sum of the depth and the velocity head is a minimum.

The hydraulic jump, as a phenomenon of nature, occurs along lake and sea shores under certain conditions of beach formations. It is found at the foot of high dams and occasionally in channels for irrigation works. It is often a source of trouble and requires special care to avoid its occurrence whenever any condition exists which causes retardation of velocity in a stream flowing much below its critical depth.

The hydraulic jump, while a common phenomenon in nature, has, so far as the authors know, been utilized only occasionally, and then solely for the dissipation of energy in flowing water.

Engineers have employed the hydraulic jump with the idea of changing a high velocity of flow, which would cause scour, into a more stable and less destructive low velocity. In no case, however, so far as the authors are aware, has an attempt been previously made to convert the energy within the jump itself into useful work.

It was thought that the churning action therein would furnish a cheap and efficient means for thoroughly mixing water, being prepared for filtration, with the chemicals applied. In order to test this hypothesis it was necessary (1) to study the action of the jump from the standpoint of a method for chemical mixing, and (2) to investigate, on a sufficiently large scale, its practicability for the conditions required in good filtration-plant design. Both of these objectives were attained as a result of the Cleveland experiments.

The original article describes extensive tests made with the hydraulic jump which proved its efficiency as a mixing device, and also showed the relation of the mixing action of the hydraulic jump to coagulation. The general conclusions as a result of this work may be summarized as follows:

1 Hydraulic jump is an extremely effective means for mixing chemicals with water to be purified.

2 The mixing effect is produced with great rapidity and with remarkable thoroughness.

3 The chemical reactions cannot take place until the chemical or chemicals are in solution and are diffused throughout the water to be treated, which latter is so many times larger in volume than the reagent solutions being applied that the value of a rapid and thorough method of mixing is obvious.

4 The energy relations of the hydraulic jump have been studied by several investigators, and the principles involved are sufficiently well understood so that it is possible to design and construct a flume in which the jump may be produced and controlled within comparatively narrow limits.

5 The loss of head through such jump may be made as low, if not lower, than is produced in any of the conventional baffled mixing chambers, hence its practicability and economy from the hydraulic standpoint.

6 The structure in which the jump may be produced is simple, requiring comparatively little space and a small amount of material for its construction. On this score its cost is far less than that of the conventional baffled mixing chamber.

7 The jump conveniently lends itself, after thorough mixing of the chemicals with the water, to any character of structure desired beyond the jump to facilitate coagulation and sedimentation. (A. G. Levy and J. W. Ellms, Engineers of the Division of Water, Cleveland, Ohio, in a paper presented before the Water Purification Division, at the Buffalo Convention, June 11, 1926, and abstracted from the *Journal of the American Water Works Association*, vol. 17, no. 1, Jan., 1927, original paper pp. 1–23, and discussion pp. 24–26, 8 figs. in original paper, *eA*)

INTERNAL-COMBUSTION ENGINES (See also Aeronautics: Engines at the Tenth Aviation Show in Paris, and The Beardmore Typhoon Engine)

National Advisory Committee for Aeronautics Universal Test Engine and Some Test Results

THIS report describes the 5-in. bore by 7-in. stroke single-cylinder test engine used at the Langley Field laboratory of the National Advisory Committee for Aeronautics in laboratory research on internal-combustion-engine problems, and presents some results of tests made therewith.

The engine is so arranged that the compression ratio and lift and timing of both inlet and exhaust valves may be varied over wide ranges while the engine is in operation. Provision is also made for the connection of a number of auxiliaries. These features tend to make the engine universal in character and especially suited for the study of certain problems involving change in compression ratio, valve timing, and lift.

Incidental to investigations of carburetor and fuel-injection engine problems considerable data have been obtained which indicate the effect of changes of compression ratio on friction horsepower and volumetric efficiency. From this and some other work it appears that with a change in compression ratio from 5 to 13, the friction horsepower obtained by motoring the engine increases by about 15 per cent. The volumetric efficiency of the engine was found to remain practically unchanged between compression ratios of 5.3 and 7.3 with carburetor operation, and between 9.5 and 13 with fuel-injection operation.

The results of some tests are also presented that show the power obtained when operating as a carburetor engine on aviation gasoline at compression ratios in excess of that which will permit full throttle as a normal engine and controlling detonation by throttling the intake charge and by varying the inlet-valve timing. For mixed-compression ratios in these tests throttling gave the least power, while variation of the inlet-valve closing time with the opening time kept fixed gave the greatest power for the conditions tried.

Among the most interesting features of this installation is the mechanism used for changing the compression ratio and the valve timing. The compression ratio is varied by moving the cylinder unit vertically, the stroke of the piston remaining fixed while the clearance volume changes.

The timing of the opening and closing of the valves is varied by the use of three-part cams. The central part of each cam is

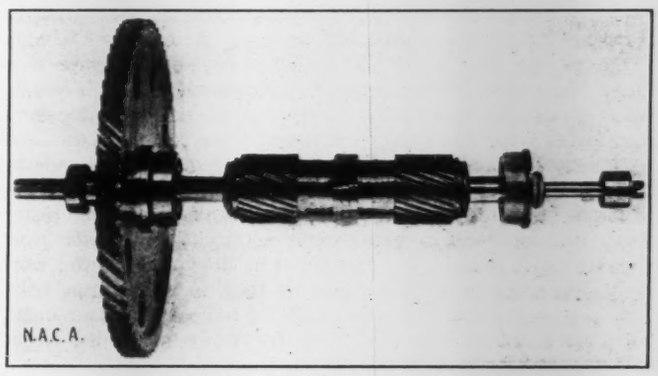


FIG. 2 CAMSHAFT ASSEMBLY—CAM PARTS DISPLACED SLIGHTLY FROM ALIGNED POSITION

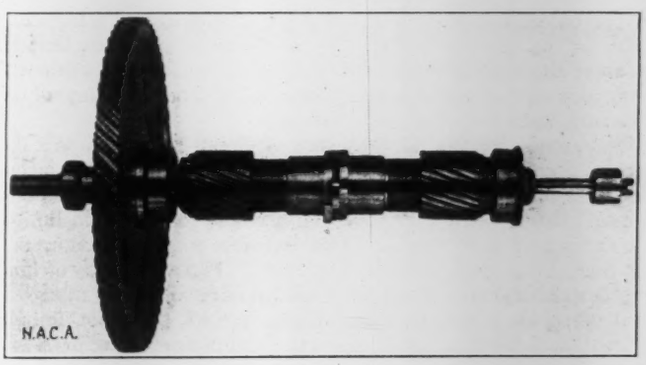


FIG. 3 CAMSHAFT ASSEMBLY—CAM PARTS DISPLACED THEIR MAXIMUM AMOUNTS FROM ALIGNED POSITION

fixed directly to the camshaft by means of splines, while the two outside parts can be rotated independently with respect to the central part and to each other. All three parts of the cam have the same contour, so that when they are aligned they act as a single broad-face cam. Displacements of the outside parts from the aligned position are made in opposite directions so that rotation of one of the outside parts varies the opening point while rotation of the other in the opposite direction varies the closing point. When both outside parts are displaced from the aligned position, the dwells of the three parts form one continuous dwell. The dwell of the movable cam parts must be at least equal to the angular variation of the parts from the aligned position. In this engine the dwell of the inlet cam is 50 crankshaft deg. and the dwell of the exhaust cam is 80 crankshaft deg. with both inlet and exhaust cams aligned. Fig. 2 shows a camshaft assembly with the three cam parts nearly aligned; Fig. 3 shows the three parts at their maximum-displacement position.

Variation of the valve lift is effected by changing the position of the valve-rocker-arm fulcrum.

Among the problems investigated by means of this engine is the effect of changes in compression ratio on volumetric efficiency and engine friction. As to the former, it was found that

the effect of compression ratio on volumetric efficiency for a considerable change in this ratio is so small that it is of little practical importance.

On the other hand, it was found that friction horsepower as measured by motoring tests increases with increase in compression ratio. In motoring tests the increase in friction with increase in compression ratio is due primarily to two causes. First, the increased pressures accompanying increased compression ratio will cause greater mechanical-friction losses, due primarily to greater piston-ring friction and piston side thrust. Second, the operations of suction, compression, expansion, and exhaust during the motoring tests may be such as to require greater work input with increased compression ratio. Due to leakage past the piston and rejection of heat to the jacket, all of the work of the compression stroke will not be returned on the expansion stroke. The difference between the work for these two strokes will increase with increase in compression ratio.

When the engine is under power the conditions are somewhat different. Piston side thrust will increase more with a change in compression ratio when the engine is developing power than in motoring tests where an increase in compression ratio is accompanied by an increase in mean effective pressure. Indicator cards taken under power show the work done by the engine on the compression and expansion strokes, and that required to overcome pumping losses on the exhaust and inlet strokes. While there are actual losses due to heat rejection and leakage past the piston during the compression and expansion strokes in power runs, indicator cards taken during power runs do not show the work required as a result of these losses as they do in motoring tests. Friction power taken from differences of indicator measurements and brake measurements gives then the purely mechanical losses, while the friction power taken from motoring tests involves a lower mechanical loss, in so far as the lesser loads produce lower friction, and also includes the lost work that results from piston leakage on the compression and expansion strokes. Brief theoretical consideration of the influence of change in compression ratio on the components of friction discussed indicates that the order of the change of friction with change in compression ratio from indicator and brake measurements may be the same as that obtained from motoring measurements.

Tests made by the Air Ministry of Great Britain in this connection are also referred to. Tests were also made for the purpose of determining mean effective pressures obtained at various compression ratios when using aviation gasoline for fuel, and limiting the detonation at the higher ratios that were considered permissible for continuous operation at a low ratio. Three methods of limiting detonation were used, as these provide different means for controlling the over-compressed engine so that it will not detonate at sea level with aviation gasoline. (Marsden Ware in Report No. 250, *National Advisory Committee for Aeronautics*, 1927, pp. 3–15, 11 figs., *de*)

Fuels for Producer-Gas-Driven Trucks

From data submitted by M. Burelle, engineer in charge of transportation industries at Lyons, the best results on the Berliet trucks were obtained with producers fed with air-dried oak without bark, containing about 20 per cent of moisture and cut into pieces 2 × 2 × 3 cm. (roughly 0.8 × 0.8 × 1.2 in.). Such wood costs about 25 francs for 100 kg. (say, $1.00 for 220 lb.). Furnace-dried wood has the disadvantage that it is apt to deposit tar in certain parts of the gas producer.

M. Burelle considers it unwise to employ producer gas in engines built for gasoline and advocates the use of special motors with increased bore and compression. One of the objections made to the operation of trucks on producer gas has been the alleged lower power developed by the engines as compared with the same engines on gasoline. It is true that notwithstanding the increase of the compression ratio which the use of producer gas makes possible, it is not feasible to obtain with an engine of the same size the same power on producer gas as is obtained on gasoline. A larger motor is therefore necessary, and with such a motor special means, such as the employment of a device to reduce the compression ratio or the use of anti-knock compounds, become imperative when a change is made to gasoline as fuel.

Among other things, the fact is brought out (by A. Grebel) that for a given tonnage of wood about three times as much mechanical energy can be produced from the wood itself as a fuel as from the same wood previously burned to charcoal. (Paper by Paul Dumanois before the Committee of Mechanical Arts of the French Society for the Encouragement of National Industry, published in *Bulletin de la Société d' Encouragement pour l'Industrie Nationals*, vol. 125, no. 12, Dec., 1926, pp. 1912–1913, *p*)

The Michell Crankless Engine

The author points out that there are at this time two totally separate and distinct Michell crankless engines. One is the invention of A. G. M. Michell, the inventor of the Michell thrust block, while the other is the invention of a German who happens to bear exactly the same name. The English Michell engine is of the swash-plate type with the cylinders arranged around the circumference of a circle. The German machine is of the internal-cam crank type, having the cylinders arranged radially with their combustion heads grouped together at the center of the circle. (G. L. Sartoris, Director Crankless Engines, Ltd., a British company, in a letter in *Engineering*, vol. 123, no. 3182, Jan. 7, 1927, p. 23, *g*)

MECHANICS

The Elastic Deformation of Pipe Bends

Under the above title Prof. William Hovgaard, of the Massachusetts Institute of Technology, has presented a paper in the *Journal of Mathematics and Physics* of the Institute,[1] in which he offers a new solution of a problem that has caused much trouble and discussion among engineers.

It has long been known that pipe bends, when exposed to forces tending to alter their curvature, show much larger deflections than can be accounted for by the ordinary formula for bending of curved solid bars, where no sensible deformation of the transverse section takes place within the elastic limit. This discrepancy has been generally ascribed to corrugations or buckles, or to stretching of the material of the pipe wall produced in the process of manufacture, but as shown in this paper the principal cause of the discrepancy is a deformation of the circular pipe section, which takes a flattened-oval form under these conditions. It can be seen at once that when a curved pipe is subject to a bending couple tending, for instance, to increase the curvature, the tensile stresses on the convex side and the compressive stresses on the concave side must have a tendency to push the wall on both sides of a transverse section in toward the neutral surface. Hereby the moment of inertia of the section is reduced, but this in itself cannot account for any material increase in curvature of the bend. The chief cause of this is that the material farthest from the neutral axis is by this deformation enabled to shirk its duty and is largely relieved of the stresses, so that the angular deflection of the bend will be much increased before equilibrium with a given bending moment is established. This was pointed out in 1911 by Dr. Th. V. Karman, who on the basis of this theory gave formulas for the deflection. In the present paper Karman's formulas have been verified not only by developing them by an entirely different method but also by experiments, in which deflection and strain measurements were made. Pipe bends for these tests were obtained from the Boston Navy Yard and from the Walworth Manufacturing Company, of Boston, and tests were carried out as a thesis for the Master's Degree by student officers in the Course of Naval Construction at the Institute.

While Professor Bantlin of Stuttgart and others have made similar tests, in which the deflections of the entire bend were measured, no measurements are known to have been made previously of the strains or of the deformation of the transverse sections. The measurements, which comprised both axial and transverse strains, confirmed in a conclusive manner the theory that the remarkable flexibility of pipe bends was due essentially to the deformation of the circular section of the pipe into a quasi-elliptic form. They showed also that the maximum lengthwise stress did not occur at the extreme points of the circular section, but

[1] Vol. 6, no. 2, Nov., 1926.

at a considerably smaller distance from the neutral axis, and that the absolute maximum stress was transverse.

Professor Hovgaard's investigation comprised not only an analysis of the tests made at the Massachusetts Institute of Technology, but also of those carried out by Professor Bantlin. A simple graphical method of analyzing the deflections of pipe bends of any form was developed and is illustrated in the paper. While in most of these tests the end flanges of the bend rested against knife edges, which permitted rotation about an axis normal to the plane of the bend, a study was made also of the case where one or both ends were to some extent restrained. By such restraint couples are induced in the bend, counteracting the couple caused by the external forces, and thus the deflections are reduced. As these couples are generally unknown, they render a scientific analysis impossible. This may explain why many earlier tests, where the end flanges were not quite free to turn, gave erratic results. The question of restraint is one of practical importance and should be carefully considered in locating the pipe bends relative to the fixed attachments of the pipes.

The formula for the angular deflection of a pipe bend proposed by Professor Hovgaard is:

$$\frac{\Delta(d\psi)}{d\psi} = K\frac{MR}{EI}$$

where $d\psi$ is the initial angle of a small segment of the pipe, R the radius of curvature of the bend at the point under consideration, r the radius of the middle surface of the pipe section, M the bending moment, I the moment of intertia of the section, E the modulus of elasticity, and K a coefficient, the value of which is given by:

$$K = \frac{48\,h^2R^2 + 10r^4}{48\,h^2R^2 + r^4}$$

where h is one-half the thickness of the wall of the pipe. It is seen that the formula for the angular deflection differs from the ordinary formula for the bending of curved bars only in the use of the factor K, which may have a value of from 1 to 5, depending on the relation between the dimensions R, r, and h.

The lengthwise bending stress is given by the formula:

$$p = \frac{KM}{I}\left(y + \frac{6\,r^2y^3}{24\,h^2R^2 + 5r^4}\right)$$

where y is the distance from the neutral axis. This shows clearly that the maximum stress does not occur when $y = r$, as it would in a solid bar.

The transverse bending stress, which is much greater and which occurs in the neutral axis, is given by:

$$p_t = \frac{3Mr^3}{8hRI}\,\frac{96h^2R^2 + r^4}{48h^2R^2 + r^4}$$

It is seen that the method hitherto used of estimating the allowable displacement of a pipe bend—viz., by prescribing a permissible longitudinal stress—is erroneous for two reasons: first, because the maximun longitudinal stress is considerably greater than that calculated by the ordinary theory, and does not occur where it should according to that theory: second, because actually the highest stress is not longitudinal but transverse and is of much greater magnitude. The curves given in handbooks and catalogs, as also in certain scientific papers, for the expansion which may be taken care of by bends of various dimensions, are based on a certain longitudinal stress, usually 15,000 or 16,000 lb. per sq. in., as calculated by the ordinary formula for bending. These curves do not rest on a rational basis.

This subject is of considerable practical interest to engineers, since numerous cases of breakdown have occurred both on shore and on board ship due to faulty design of pipe lines. The next step in this study will be to correlate the results here attained with engineering practice, but for this purpose it is necessary to measure displacements, deformations, and stresses in pipe bends under actual operating conditions. It is the intention eventually to make such further study at the Massachusetts Institute of Technology (Wm. Hovgaard, Professor at Mass. Inst. Technology, in *Journal of Mathematics and Physics*, vol. 6, no. 2, Nov., 1926; reprinted in *Publications from the Massachusetts Institute, of Technology*, vol. 62, no. 64, Pub. Serial no. 434, pp. 69–118, 18 figs., *teA*)

Acceleration Stresses in Wire Hoisting Ropes

IN PREVIOUS discussions on stresses in hoisting ropes little has been said concerning the effect of the elasticity of the rope itself on the stresses due to acceleration. This became important with the advent of the motor-driven hoist, as the elastic properties of the rope seemed to introduce periodic acceleration stresses in the rope. The majority of hoisting engineers make the assumption of contant acceleration at the drum. Under the older method of calculating acceleration stresses this would be true with a constant-torque motor, but if stresses varied as this paper attempts to show they do, constant torque would not give constant acceleration, although the velocity-time curves obtained in the full-size test

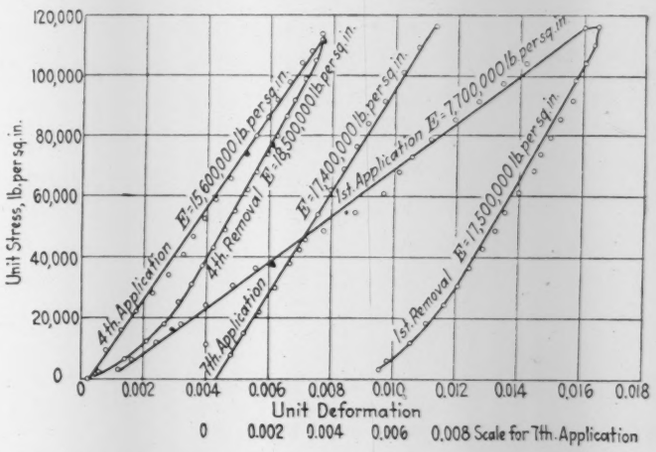


FIG. 4 STRESS-DEFORMATION CURVES FOR 1¼ IN. CAST-STEEL WIRE ROPE USING BERRY STRAIN GAGE

described in this paper showed that they approach rather closely to this condition, at least as nearly as could be measured.

The author discusses the mechanical problems involved and uses in this connection acceleration-time, velocity-time, and distance-time curves. To verify the conclusions given a series of experiments were made and are described in this paper, among others being a field test on a mine hoisting cable in which a telemeter was used as a recording device.

The results of these tests led the author to ask whether the short life of hoisting ropes is not due to excessive stress, which in its turn is due to a neglect of the full effect of acceleration stresses. Mine laws in many states and general practice recommend the use of a factor of safety of five. Calculations involving the theoretical acceleration stresses will reduce this in many cases until the factor is little more than two. The endurance limit of steel is little more than one-half of the ultimate strength. Thus the greatest stress set up under normal conditions of hoisting is barely below the endurance limit in many cases. The author attempts to prove it by a calculation involving the rope and hoist at a test mine, and show that in that case the factor of safety is only 2.75, so that any unusual load acceleration, shock, or starting speed may increase the stress to or above the endurance limit. On the basis of his investigation the author recommends certain formulas for the design of hoisting rope.

The author also made extensometer tests on five sizes of rope to ascertain the modulus of elasticity of wire rope. Fig. 4 is the stress-strain diagram for the 1¼-in. specimen and is typical,

TABLE 1 VALUES OF MODULUS OF ELASTICITY AFTER STRESSING WIRE ROPE BEYOND THE ELASTIC LIMIT

Rope diameter in.	Observed breaking load, lb.	Breaking load from catalog, lb.	Ultimate strength, lb. per sq. in.	Values of Modulus of Elasticity — First application	Average down	Fourth application	Seventh application
⅜	8,920	9,600	146,710	.....	16,400,000	14,400,000	.....
½	17,100	16,800	155,455	10,500,000	18,800,000	15,000,000	17,200,000
¾	38,275	37,200	158,800	6,000,000	12,400,000	.....	10,400,000
1	69,850	60,000	155,500	6,000,000	18,000,000	16,800,000	**14,100,000**
1¼	109,000	94,000	166,400	7,700,000	16,500,000	**15,600,000**	**17,400,000**

while Table 1 gives the values of the modulus of elasticity after stressing wire rope beyond the elastic limit.

A pronounced twist was noticed in the specimen during the first application of load, but was hardly noticeable thereafter. This would affect the value of E (modulus of elasticity of the rope in lb. per sq. in.) when the first type of instrument was used, resulting in a somewhat smaller value than the actual. The Berry strain-gage readings would be affected much less than the others. (G. P. Boomsliter, Department of Mechanics, West Virginia University, in *Paper No. 1641-A of The American Institute of Mining and Metallurgical Engineers*, 20 pp., 11 figs., *e*. Abstracted from advance copy.)

PIPING (See also Engineering Materials: The Expansion Coefficient of Cast-Iron Pipe)

Linings and Coverings for Water Pipes

AMONG other things this paper is of interest because it was stated sometime ago that the U. S. Steel Corporation had acquired a process for lining steel pipe and was building a plant at Lorain, Ohio, where it would be applied. It was stated informally at that time that the process under consideration was originated by Benjamin Talbot, of England, the author of the paper.

The Talbot hydrocarbon process consists in applying by centrifugal force a bituminous composition to the interior of the pipe, producing a lining of any desired thickness. For most purposes a lining $^1/_4$ in. in thickness is considered most satisfactory.

The composition itself is prepared by intimately mixing a finely ground inert filler with specially selected bitumen. The essential feature of the filler is that it shall be reducible to a finely ground powder, and shall be chemically inert as far as possible and not reactive in any way with the bitumen. For this purpose may be used ground granite, acid open-hearth slag, slate dust, dry clay, etc.

The speed of rotation and temperatures can be so regulated that under centrifugal force sufficient bitumen may be exuded to the surface so as to give a skin of comparatively pure bitumen, back of which is a tough, elastic bed of lining material entirely inert to such chemical action as is liable to be met with in water.

In the discussion it was stated that the mixture used in England consists of about 62 per cent of ground rock, the remainder being asphaltic bitumen. When using bell-and-spigot pipe $^1/_4$ to $^3/_8$ in. of this material is left in the bell itself, so that when the spigot of another length enters there is an insulating lining separating the two lengths of pipe. (Benj. Talbot in *Journal of the New England Water Works Association*, vol. 40, no. 4, Dec., 1926, original paper, pp. 446–450 and discussion pp. 450–456, *d*)

POWER-PLANT ENGINEERING (See also Mechanics: Elastic Deformation of Pipe Bends)

The Effect of Direct Heating Surfaces on Efficiency

THE author claims that an excess of furnace water cooling, or more correctly, direct heating surface acted upon by the radiant heat of the fire, causes an increase in exit flue-gas temperatures, and consequently a lower boiler efficiency, all other conditions being equal. This he ascribes to the fact that excess direct heating surface reduces the initial temperatures from which energy radiates in proportion to the fourth power of the absolute temperature. The well-type furnace and short-flame methods of burning powdered coal are said to have shown from 2 to 5 per cent higher efficiencies than were obtained by the long-flame method; this is ascribed to combustion being completed without being affected by the direct heating surface, which results in higher initial temperatures and a correspondingly increased rate of heat transfer by radiation. In this connection the author describes an installation where a boiler was constructed with 65 sq. ft. of direct heating surface exposed to the fire and then changed to 95 sq. ft. of direct heating surface. Curves given in the original article indicate that with 95 sq. ft. of direct projected area the temperature under the tubes was 1950 deg. fahr., while in the boiler with the smaller area the same temperature was 2300 deg. fahr. The curve for the second boiler also shows that the gas temperatures drop more readily, due to the absorption of radiant heat by the first and second rows of boiler tubes, and continuing below the curve for the first boiler it indicates that more heat was absorbed with the least amount of direct tube surface, higher furnace temperature, and consequently lower exit gas temperature. (J. Gould Coutant, Mem. A.S.M.E., in *Combustion*, vol. 16, no. 2, Feb., 1927, pp. 99–100, 2 figs., *e*)

RAILROAD ENGINEERING

A New Locomotive Throttle Valve

DESCRIPTION of the American multiple throttle, which is said to be a new type of front-end throttle introduced during the past year. It consists of an improved superheater header of either the type A or type B design, containing the throttle valves located in the superheated-steam compartment on the forward side. This combination can be installed in practically every superheater locomotive containing a normal through-bolt header.

The throttle valves are of comparatively small diameter: $4^1/_8$ in. They are similar in construction to automobile-engine valves and easy to keep tight, and are operated by a camshaft similar

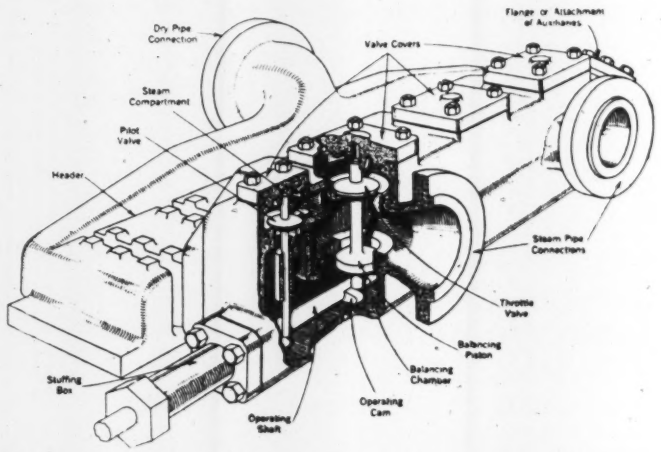


FIG. 5 AMERICAN MULTIPLE THROTTLE IN COMBINATION WITH SUPERHEATER HEADER

to that used on an automobile engine. They are so nearly balanced that only a slight effort is required to move them. This balancing is accomplished by means of a pilot valve, which opens first and admits steam to a balancing chamber preliminary to the opening of the main valves. The main valves then follow in succession, providing a perfect graduation in the supply of steam to the locomotive cylinders.

The small steel valves used in the throttle are not affected by high temperatures, so they are easily kept tight and remain tight. This eliminates steam leaking through the throttle, and the danger of the locomotive moving when unattended around engine houses, terminals, and yards.

A removable cover is provided directly over the superheater header, in back of the stack on the smokebox, so that the valves are easily accessible. In case it should be necessary to do any work on the valves, they may be reached through the opening without having to enter the front end. With locomotives equipped with a shut-off valve in the dome, the throttle may be worked on while there is steam in the boiler. The camshaft stuffing box can also be packed while there is steam in the boiler. There are no bolts, rings, pins, cotter pins, rods, links, studs, nuts, or other parts to become loose and broken and cause trouble in this throttle.

Through the use of this type of throttle the number of steam-pipe joints in the front end is reduced to a minimum. This combination of throttle and superheater header requires only the usual steam pipes leading from the header to the main steam cylinders. The additional weight of the header with throttle combined over that of the header alone is only 400 lb. approximately. (*Railway and Locomotive Engineering*, vol. 40, no. 1, Jan., 1927, pp. 12–13, 7 figs., *d*)

Heat-Exchange Losses in Locomotive Cylinders

A THEORETICAL investigation of the subject in the course of which, among other things, calculations of heat losses are made from data on more than a score of German and American locomotives and an equation is derived to determine the steam losses due to cooling at admission to the cylinder. The author attempts to show also that where there is a sufficient superheat the magnitude of the losses is essentially determined by the engine speed and output.

The author claims that there is comparatively little reliable information in printed form concerning the steam loss due to the heat exchange between the steam and the cylinder walls of locomotive engines. Some of the data given in books which he quotes are unreliable.

Any thermal investigation of this subject has to start with some assumption concerning the state of the steam at some one point of the steam curve. The assumption made by Hirn to the effect that within the region of saturation the steam at the beginning of compression is dry and saturated appears likely to be true also for the case of superheats which are not carried to a very high extent. This is shown in the original article by an analysis of conditions at admission and exhaust.

The author claims that where there has been a high initial superheat it becomes necessary to admit the existence of a certain

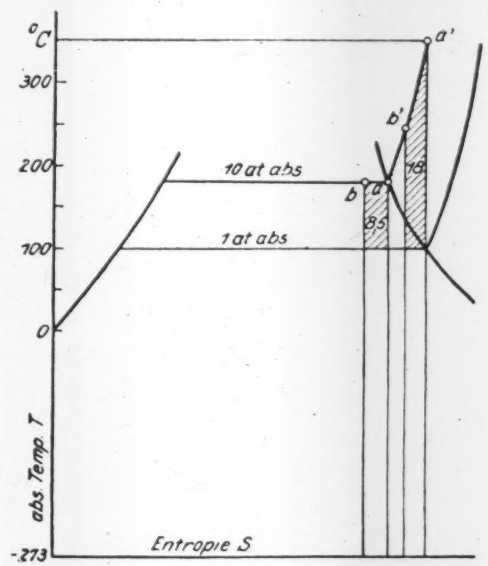


FIG. 6 TEMPERATURE-ENTROPY DIAGRAM OF HEAT LOSSES AT EQUAL PRESSURE FOR SUPERHEATED STEAM (a' AND b') AND SATURATED STEAM (a AND b)

superheat, even for the final state during the exhaust. Furthermore, attention is called to the fact that because of the comparatively small mass of residual steam in comparison with the live incoming steam, the difference which might result from the above assumption can have only a slight influence on the final result.

From this the author proceeds to sketch out his method of calculation, which he follows by an example in which all the necessary computations are carried out for a German locomotive previously described in a German book. He also gives 21 curves referring to five American locomotives. He states, however, that the absolute values of the heat exchange between the steam and the cylinder wall do not indicate the degree to which the efficiency of the engine is affected by the cooling of the steam. He therefore asks regarding the fraction of the steam actually consumed that would have been saved in each case had there been no heat exchange at all, all other factors remaining unaltered. He claims that this will bring out the advantages of the superheated-steam process, due to its better approach to the ideal Rankine cycle as compared with the wet-steam process. He gives a table (Table I of the original article) in which, among other things (column IV), the efficiency of the actual processes for the various locomotives is expressed in percentages of the Rankine cycle, which means that the ratio of the steam consumption of the Rankine cycle to the actual steam process is given. As limits for the Rankine cycle should be considered here the state of the steam in the branch pipe between the superheater and the valve chest and a pressure of 1 atmos. abs. It will be noticed when the efficiency is calculated in this way that the figures for superheated steam are not as superior when compared with those for saturated steam as one would expect from the values for the reduction of the heat exchange given elsewhere in the original article.

The author explains this by a reference to Fig. 6 and points out that there is no true basis for comparing the loss through heat exchange with the absolute magnitudes of the heat given up. In Fig. 6, a denotes the state of the dry saturated steam and a' that of superheated steam of the same pressure. If from both kinds of superheated steam the same amount of heat be abstracted without changing the pressure so that the new states of steam will be described by b and b', it is obvious that the share of heat abstracted from superheated steam (which, in some later working process, would be converted into mechanical work and is therefore the only one that is of interest in this connection) is larger than it is in the case of saturated steam. For example, let there be at a steam at 10 atmos. abs. pressure, dry and saturated, with a heat content of 663 kg-cal. and an adiabatic heat drop down to 1 atmos. abs. of 93.5 kg-cal. The heat abstraction without change of pressure is assumed to be 48 kg-cal. and hence the heat content at b becomes 615 kg-cal. and adiabatic heat drop 85 kg-cal. The thermodynamically usable share of abstracted heat is therefore $93.5 - 85 = 8.5$ kg-cal. In the case of superheated steam at a' with 10 atmos. abs. pressure and 350 deg. cent. temperature, the heat content is 753 kg-cal. and the adiabatic heat drop down to 1 atmos. abs. is 121 kg-cal. If the amount of heat abstracted be again 48 kg-cal., then the heat content at b' becomes 705 kg-cal. and the adiabatic heat drop is 103 kg-cal. The usable share of the abstracted heat is therefore $121 - 103 = 18$ kg-cal. as compared with 8.5 in the case of dry saturated steam.

Therefore, while the absolute amount of the heat exchanged is very small in the case of superheated steam as compared with saturated steam, this is partly compensated by the fact that thermodynamically, superheated steam is much more sensitive toward heat losses than saturated steam. The author attempts to show the heat losses in an actual machine by a calculation based on the comparison of an actual indicator diagram with that of an assumed process. He presupposes at first that the heat exchange during compression may be neglected and that the state of the steam at initial admission is the same as its state in the actual diagram. He assumes, however, that in his imaginary process all heat loss to the walls during admission is avoided and yet in this process the pressure varies during steam admission in the same manner as in the actual process. This can be theoretically obtained by proper increase or decrease of the valve opening and hence by decrease or increase of the throttling. He proceeds then to the calculation of what happens in both cases and comes to a number of conclusions affecting both his imaginary process and the precision of his methods of calculation. Among other things, the consideration of volume changes through cooling at admission is again used to show the high sensitiveness of superheated steam as compared with saturated steam. In this case he compares superheated steam at 10 atmos. abs. pressure, specific volume 0.199 cu. m. per kg. (3.19 cu. ft. per lb.) and heat content of 663 kg-cal. per kg. with superheated steam likewise at 10 atmos. abs. pressure, 267 deg. cent., specific volume 0.2473 cu. m. per kg. (3.97 cu. ft. per lb.) and heat content of 711 kg-cal. per kg. If in both cases 48 kg-cal. are abstracted the saturated steam will lose in volume 10 per cent. The originally superheated steam will be brought to the condition of dry saturated steam with the specific volume of 0.199 cu. m. per kg. (3.19 cu. ft. per lb.) and will experience a loss of volume equal to

$$\frac{0.247 - 0.199}{0.247} = 1.94 \text{ per cent.}$$

Because of this, it is correct to consider cylinder condensation as the main source of heat losses only in so far as saturated steam loses more heat to the walls. It is, however, entirely erroneous to say, as is done quite frequently, that superheated steam

loses no heat because "it does not condense and does not lose its ability to perform work," and it is likewise erroneous to say that the volume losses of superheated steam are inconsiderable. The author would like to see the expression "cylinder condensation" completely eliminated and replaced by some more general conception, such as heat exchange with the walls.

The conclusion to which the author arrives is that in express locomotives, at least of the type of the large American locomotives which he has investigated, there is little of real value that can be done by way of improving heat-exchange conditions. In the case of slow-speed freight locomotives, however, there is always a loss of 15 to 20 per cent which can be counted upon, and these figures are still higher for European locomotives. (Dr. of Engrg., Fritz Loewenberg, Schenectady, N. Y., in *Zeitschrift des Vereines deutscher Ingenieure*, vol. 71, no. 1, Jan. 1, 1927, pp. 15–19, 6 figs., *t*)

Maffei Turbine Locomotive for the German State Railways

DESCRIPTION of an experimental unit designed for heavy express service and said to develop 2500 hp. with a total weight of 229,000 lb. The general design and construction of this locomotive was made as far as possible similar to that of the standard reciprocating Pacific-type locomotives recently adopted by the German State Railways. The boiler pressure is 324 lb., and because of this and the saving of time by the condenser, the dimensions of the normal locomotive boiler were considerably reduced. Shortening the boiler and reducing the smokebox dimensions created additional space on the front end of the locomotive, making room for the turbine and the reduction gearing. The power of the turbine shaft is transmitted by two pinions through reduction gearing to a jackshaft, and from this shaft to the main connecting rods and the six coupled driving wheels.

Two surface condensers are located on each side of the boiler. The exhaust piping to these condensers passes through the center supporting yoke of the boiler. A suction-draft fan, directly connected to a small turbine, is fixed to the inner side of the smokebox door, and serves to eject the waste gases. The air of the condenser is removed by two single-stage air-suction steam ejectors. The condensate is removed by a pump directly connected to a piston feedwater pump. A Westinghouse air compressor and small turbine-driven dynamo for electric lighting, etc., are also provided.

The tender has been considerably increased over the standard length, the forward part having storage space for fuel and feedwater. Adjoining this is a small space for the turbine which drives the air fans and the cooling-water pump. The remaining portion is occupied by the cooling installation, which consists essentially of a spray cooler. The water flows downward over flat metal sheets, while the cool air is admitted through the sides of the tender and passes over the flat metal surfaces exposed to the spray, finally being ejected by two fans placed horizontally on the roof of the tender.

The price of the turbine locomotive will be higher than that of the reciprocating locomotive. Of the coal consumed, 15.6 per cent of the total heat can be utilized at the crankpins when the locomotive runs at the rate of 43.5 m.p.h., whereas the express reciprocating-type locomotive of standard construction will give a value of 7 to 8 per cent. It has been estimated that 1 hp. at the jackshaft will absorb 7280 B.t.u., or with coal having 12,780 B.t.u., 1.26 lb. of coal per horsepower (including the steam used for the auxiliary machinery). In the winter the total net efficiency will be increased, due to the train heating and it is then expected to increase up to 20 or 22 per cent.

The turbine is set above the engine truck with its axis at right angles with the center line of the locomotive. The forward-drive and the reverse-drive turbines are enclosed in the same housing.

The forward turbine consists of two disks in the high-pressure end, each containing one row of blades at the rim, followed by an impulse wheel and five reaction wheels of suitable diameters. The end thrust is counterbalanced by a balance piston at the high-pressure end.

The backward-drive turbine consists of a velocity disk of smaller diameter having three rows of blades revolving in a vacuum while the forward-drive turbine is in action. The steam expands in the nozzles of the backward-drive turbine from admission to vacuum and exerts but little reaction effort on the blading. The housing of the backward-drive turbine is located inside of the main turbine, and its construction provides a guide channel so arranged that the exhaust from both turbines is led to the same outlet without interfering; that is, it prevents the steam from one from entering the blading of the other. It is evident that the backward-drive turbine cannot produce the same effect as the forward, but this is a secondary question for an express locomotive.

A novel construction was created in order to solve the important question of suitable shaft in the smokebox. As may be seen from the drawings in the original paper, a small high-speed turbine is located in the door of the smokebox, which operates with superheated as well as with saturated steam. It is directly coupled to a draft fan of special design. This fan is extremely simple in design and form, made of non-rusting Böhler steel, and ejects the gases from the smokebox.

The draft fan operates at a speed of from 6000 to 7000 r.p.m. This unit and its housing form the projecting point of the door which receives a strong cooling effect on the front bearing and the oil chambers directly adjacent while the locomotive is running.

The turbine casing has ribs cast on the outside to cause the air to circulate around the turbine and also for the purpose of cooling the bearings.

The admission valve of the turbine is controlled directly by the engineman in the cab. The exhaust steam from the turbine flows into the second feedwater heater, and is controlled by a valve that admits the steam at a pressure in the neighborhood of 37 lb. per sq. in. gage. In the case this heater is fully charged, the steam is turned into a low-pressure stage of the main locomotive turbine.

This draft system was thoroughly tested and it was found that the desired pressures could be obtained with high efficiencies. It has the advantage of high speed, which enables it to be coupled up directly to a high-speed turbine. The speed need only be adjusted by the throttling valve and it will remain constant, regardless of variations of the gases or other conditions. No additional regulating devices such as a safety cut-out, etc., are necessary.

The rear and greater part of the tender is occupied by the cooling installation, but the space thus used is only about one-tenth of that usually required for stationary installations. Extraordinary conditions being present made it imperative to find new methods and apply new principles. It was found by actual experiment to be very important to prevent drop formation, as a drop of water is carried away by the current of the cooling air. The cooling air must follow a line of least resistance in order to save power for ventilation, vibration must be eliminated, and all parts must be so located as to be easy of access. It is not possible to cool by means of a blast of air on account of the great amount of space required.

It must be considered that from about 16,000,000 to 18,000,000 B.t.u. per hr. will have to be taken care of, a figure which is too great for air ventilation only. Air is admitted on both sides of the tender, passing through air deflectors, and is ejected by means of two horizontal ventilators placed in the roof. The compartment for recooling is subdivided into various cooling elements. These elements, of which there are 48, consist of closely packed perforated sheet-copper plates which are separated by pass pieces and held together by bolts. The air passes between the copper plates in an opposite direction from the downward-flowing cooling water, which flows in sheets, thus avoiding drop formation.

The experiments proved that this construction insures the greatest economy of water and that the loss of water was not any greater than the evaporation determined by calculation. It is evident that with the cool water the temperatures mentioned can create a satisfactory vacuum. At full load the locomotive has an average vacuum of from 80 to 90 per cent, which increases at a lower load. It is impossible under these circumstances to maintain a lower water temperature in the reservoir and begin the next period of heavy work with a better vacuum. (J. J. Melms, in *Railway Mechanical Engineer*, vol. 101, no. 2, Feb., 1927, pp. 78–84, illustrated *dA*. Compare *Zeitschrift des Vereines deutscher Ingenieure*, vol. 70, no. 47, Nov. 20, 1926, pp. 1565–1572, 22 figs. and one plate of drawings, *dA*)

A British 4-Cylinder Express Passenger Locomotive

DESCRIPTION of a new 4-6-0 type four-cylinder simple express passenger locomotive recently placed in service on the Southern Railway of England and named *Lord Nelson*. The cylinders are arranged two inside and two outside the frames, with the inside cylinders placed slightly in advance of the outside ones. There are eight separate impulses per revolution to the wheels, this resulting from the special disposition of the crankpins, by means of which the individual exhausts from both ends of all cylinders agree separately instead of the usual arrangement of synchronizing exhausts giving four beats per revolution of the wheel.

The revolving and reciprocating parts have been made as light as possible by the use of high-tensile steel. (*Railway and Locomotive Engineering*, vol. 40, no. 1, Jan., 1927, pp. 1–2, *d*. Compare article immediately following in same journal by A. Curran, entitled The 4-6-0 Type Locomotive in the U. S.)

SAFETY ENGINEERING (See Air Engineering: Explosions in Air Compressors of the Reciprocating Type)

SPECIAL MACHINERY (See Mechanics: Acceleration Stresses in Wire Hoisting Ropes)

SPECIAL PROCESSES

Production of Sulphuric Acid and Ammonium Sulphate from Calcium Sulphate

Two processes have been developed for the production of sulphuric acid and (incidentally) ammonium sulphate from calcium sulphate (gypsum). The first of these is a wet process in which gypsum is treated by a carbonate of ammonium or a mixture of carbon dioxide and ammonia. This process is operated on a large scale by the Baden Aniline and Soda Works in connection with the production of synthetic ammonia by the Haber process. The Dye Factories Co., formerly Fr. Bayer, developed a process for the production of anhydrous sulphurous acids and hydraulic cements out of plaster. This process has now been developed to the point where about 200 tons of material are treated daily. This latter process was described in a French patent no. 428,019 issued in 1910 to L. P. Basset, but was not applied commercially until it was taken up in Germany in 1919. (J. H. Frydlender in *Revue des Produits Chimiques*, Sept. 30 and Oct. 15, 1926, abstracted through *Le Génie Civil*, vol. 40, no. 6, Feb. 5, 1927, pp. 153–154, *d*)

The Bowie-Gavin Process for Cracking Heavy Oils

THIS process is of particular interest because it is believed to be applicable to the recovery of oil from oil shales or oil-soaked sands or shales.

In 1916 and 1917 the Bureau of Mines spent much time and money attempting to perfect a process for cracking heavy oils and tars, but was unable to overcome the difficulties caused by the large amount of free carbon produced. The inventors of the Bowie-Gavin process, while examining the results of an experiment in the retorting of oil-soaked shales, noticed that the oil produced had a distinctly "cracked" odor, and that in its production the free carbon liberated during the destructive distillation did not adhere to the sides of the retort or deposit in the vapor lines, but was entrained in the shale that contained the oil. These facts suggested the possibility of overcoming the carbon difficulties in cracking processes by mixing inert materials in proper proportion with the oil before it entered the cracking zone.

The process thus devised, termed the "Bowie-Gavin process," gave remarkable results. For instance, asphalts and tars of such heavy gravity as to remain virtually solid at ordinary temperatures could be converted into a cracked oil having a gravity of from 20 to 24 deg. A.P.I., with a loss in volume of 12 to 15 per cent. This loss, as stated before, consisted of fixed gases and carbon; the former is very valuable as fuel, as its heating value is about 1300 B.t.u. per cu. ft. against 550 B.t.u. per cu. ft. for San Francisco city gas.

The preliminary tests indicated that this process would give a relatively high yield of cracked oil—from 80 to 86 per cent by volume—and the fact that the carbon did not stick to the sides of the retort or collect in the vapor lines but was entrained in the inert material, with which, when the proper mixture had been made, it could easily be removed from the retort. The gravity of the cracked products appeared to range from 15.8 to 29 deg.

A number of runs on experimental machines were made, the largest of these being an 8-ft. semi-commercial unit. The mechanical difficulties seemed to have been overcome, but not enough data were collected to give reliable information as to the cost of operation by this process. (C. P. Bowie in *U. S. Bureau of Mines Technical Paper*, no. 370, 1926, pp. 1–42, numerous tables and illustrations, *edA*)

Artificial Fertilizers and Liquid Fuels

THE economic success of the production of many kinds of liquid and gaseous fuels from coal depends to a greater or less extent, as the case may be, on the possibility of selling some of the by-products. Hitherto the most valuable by-products, namely, compounds of ammonia, have found their chief market in the form of fertilizers, and have thus come into competition with other fertilizers. Hence anything that affects the fertilizer market today becomes of interest to the mechanical engineer, in that it may react on the production and price of at least some of the raw materials of power generation: gaseous, liquid, and—ultimately—solid. The conditions in the German chemical industry have a material bearing on this aspect of the fuel problem. At the close of the war Germany occupied a position of supremacy in the field of manufacture of synthetic dyes and of pharmaceutical and photographic reagents and products. However, the war forced the other nations to develop similar industries of their own, and while Germany is still doing business in these lines on a large scale, her former exclusive position is gone forever. She has been forced to turn her attention to other lines, and is doing it apparently with excellent success, especially as regards the manufacture of synthetic products in the heavy chemical industries. The story of synthetic methanol is well known. The intensive work done by the I. G. (German Chemical Trust) in the development of liquid fuel from coal is also well known. Less well known though important is the work that has been done in the development of artificial fertilizers, and it is this story that will be told here on the basis of an address made by Raymond Berr, General Manager of the Kuhlmann Chemical Works, before the French Society of Civil Engineers.

The problem of producing synthetic ammonia by the direct union of nitrogen and hydrogen may be considered as solved definitely. There are several processes in successful operation, such as the Haber, Claude, Fauser (see MECHANICAL ENGINEERING, vol. 45, no. 10, Oct., 1923, p. 600), and Casale. A new process the Urfer, has recently appeared in which low pressures (16 to 18 atmos.) are used, with alkaline metals as catalyzers. As a matter of fact, however, the machinery for handling high-pressure processes has been developed to such an extent that the employment of low pressures, while attractive, is no longer of primary importance.

The difficulty in all of these processes that remains to be overcome is the production of hydrogen. Hydrogen can be made from water gas, but the disadvantage of this method lies in the fact that carbon dioxide is obtained as a by-product and there is no sufficient market for it. In France hydrogen is produced from coke-oven gas, and this process promises to become satisfactory as soon as proper methods have been developed for recovering the heat lost in the process. The Claude process of fractional refrigeration is satisfactory in some respects, but requires large expenditures of power and gives as by-products ethylene and methane, for neither of which is there a sufficiently large market.

The next question is, What is the best method of employing ammonia for making fertilizers? The method most commonly used today is that of converting it into sulphate of ammonia, but this has two disadvantages. In the first place, sulphuric acid is a costly "background," reducing the nitrogen content in the final product in some cases as much as 20 per cent. In the second place, which is still more important, sulphate of ammonia is apt to increase the acidity of the soil to a point where it be-

comes detrimental to plant growth. Chlorhydrate of ammonia has been proposed and is under consideration, while Claude has made the very interesting suggestion of substituting for sea salt in the Solvay process sylvinite, a double chloride of sodium and potassium found in potash mines. The Solvay reaction will take care of the sodium and as a by-product will be obtained the potassium in the guise of a double chloride of potassium and ammonium, with a content of 40 per cent of fertilizer material. This reaction would combine three important industries, the soda, potash, and nitrogen.

The Germans, however, have gone along an entirely different line, and one apparently of great promise. What they are trying to do is to make phosphorus compounds a background for the nitrogen in fertilizers. As a matter of fact, phosphates of ammonia, in particular diammonia phosphate, seem to give an excellent fertilizer combining phosphorus and nitrogen, both of which are essential to plant growth. Diammonia phosphate in particular shows 53 per cent of anhydrous phosphoric soda and 21 per cent nitrogen. Hence 100 lb. of this material would replace 350 lb. of superphosphate fertilizer and 100 lb. of sulphate of ammonia. What is most important is that with the process developed it is no longer necessary to employ coke-oven gas as a source of hydrogen. The development has gone so far that at the end of 1926 the plants of the German Chemical Trust at Pisteritz were working day and night building a unit that would produce 100 tons of phosphorus a year. In addition to what M. Berr has stated above, it may be said that, judging by what took place, near the end of the World War, the white variety of phosphorus promises to become a military material of the utmost importance. (Paper by Raymond Berr read on Dec. 21, 1926, before the Society of Civil Engineers of France, abstracted through *La Nature*, no. 2754, Feb. 5, 1927, pp. 127–130, *gA*)

THERMODYNAMICS (See also Railroad Engineering: Heat-Exchange Losses in Locomotive Cylinders)

Loss of Heat from the External Surface of a Hot Pipe in Air

DATA of a research conducted at the National Physical Laboratory, Teddington, England. In this case the tests were made on two electrically heated pipes, and it was found that the results agreed quite closely with each other as well as with the results obtained at low temperature by the steam-condensation method and also with some results previously obtained from a 9-in. pipe. The two electrically heated pipes were not arranged in the same way. The results are given in the form of tables and curves.

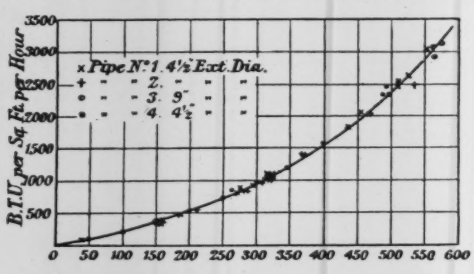


FIG. 7 LOSS OF HEAT FROM THE EXTERNAL SURFACE OF A HOT PIPE IN AIR

As regards the influence of pipe diameter on the heat loss per unit area, it has been assumed that for cylinders above 5 in. in diameter the heat loss by convection per unit area is independent of size. The relative magnitudes of heat loss by radiation and convection were estimated for theoretical purposes, and expressions for the two are given.

The loss in B.t.u. per sq. ft. per hr. is shown graphically in Fig. 7. (Ezer Griffiths, Doctor of Science, and C. Jakeman, in *Engineering*, vol. 123, no. 3182, Jan. 7, 1927, pp. 1–4, 15 figs., *e*)

TESTING AND MEASUREMENTS (See Internal-Combustion Engines: National Advisory Committee for Aeronautics Universal Test Engine and Some Test Results)

VARIA

Use of Power in American Steel Mills

IN 1926 the United States produced in excess of 39,000,000 tons of pig iron, the total world production being approximately 76,000,000 tons. Production of steel ingots and castings in the United States was over 48,000,000 tons, out of a world production of 91,000,000 tons. A comparatively small amount was exported, so it is obvious that domestic consumption per head of population is many times in excess of that of other countries.

Consumption of steel per head in 1900 was approximately 360 lb.; in 1926 it was 930 lb. The figure has been increasing continually, so that total requirements are growing faster than our population and there is no indication of any limit. (For the remainder of the world, with a population of 1,700,000,000, the consumption is only 62 lb. per head, or one-fifteenth that of the United States.)

Approximately 470,000 persons are employed in the steel industry. The amount paid annually in wages and salaries is between $850,000,000 and $900,000,000.

With only a small fraction of the number of men employed around a blast furnace compared with the middle of the nineteenth century, we produce 700 to 800 tons of pig iron per day against 25 to 50 tons, and at a much lower unit cost. Wages have probably quadrupled, and supplies, instead of being obtained close to the furnace, are now brought hundreds of miles by boat and rail.

To counteract the great rise in cost which would have resulted from increasing wage rates and reduction in working hours during the past few years, it has been necessary to substitute machinery for manual operations and to speed up existing units by various means, all requiring more power. While no reliable statistics are available, figures of one plant indicate an increase in production per man of about 35 per cent within the last 10 years, in spite of the elimination of the 12-hour day.

It is estimated that the total amount of power used in the industry in 1926 was equivalent to about 7,000,000,000 kw-hr. Approximately 75 per cent of the power was generated in the mills and about 25 per cent was supplied from outside sources, largely from central-station plants. The approximate rating of motors used in steel mills aggregates 3,500,000 hp., and of this total somewhat over 1,000,000 hp. is driven by purchased power.

The present tendency regarding development of power in steel mills depends upon the type of plant. In those plants with blast furnaces it is believed that the future practice will be to install efficient steam-driven turbo-blowers and turbo-generators. Boiler plants will be developed to burn surplus blast-furnace gas economically, and provision for supplementary fuel will be frequently installed where low-grade fuel is a by-product in the plant, as, for instance, coke braise. However, it will usually be found to be more satisfactory to burn solid fuels independently of the blast-furnace gas, unless they are first pulverized. In some cases, where the blast-furnace gas is insufficient to supply the total power needs, pulverized coal will be used advantageously with the same boiler settings that are suitable for blast-furnace gas.

There will be a tendency to interconnect these plants with central-station plants, so that when excess power is available it can be delivered to the central station and the fuel value of the excess gas rendered available. At other times, when the available gas is insufficient for the plant's power needs, power will be purchased from the central station. This is an important matter for central stations and steel plants to consider, and undoubtedly it can be worked out to the economic advantage of both.

In the case of steel plants without blast furnaces but located where central-station power is available, it is believed that power can be purchased to advantage instead of installing an individual power plant. This has been demonstrated in many cases and it is doubtful if any plant of this nature being built today will consider the investment of money in a power plant of its own if central-station power is available at reasonable cost. The steel plant is justified in installing a generating plant only if it thereby uses fuel that would be otherwise wasted. (W. Sykes, Consulting Engineer, Inland Steel Co., Indiana Harbor, Ind., in a paper read before the Mid-West Power Conference, Chicago, Feb. 16, 1927, Abstracted through *The Iron Age*, vol. 119, no. 9, Mar. 3, 1927, p. 635, *g*)

The Conference Table

THIS Department is intended to afford individual members of the Society an opportunity to exchange experience and information with other members. It is to be understood, however, that questions which should properly be referred to a consulting engineer will not be handled in this department.

Inquiries will be welcomed at Society headquarters, where they will be referred to representatives of the various Professional Divisions of the Society for consideration. Replies are solicited from all members having experience with the questions indicated. Replies should be as brief as possible. Among those who have consented to assist in this work are the following:

ARCHIBALD BLACK,
Aeronautic Division
H. W. BROOKS,
Fuels Division
R. L. DAUGHERTY,
Hydraulic Division
JAMES A. HALL,
Machine-Shop Practice Division
CHARLES W. BEESE,
Management Division
G. E. HAGEMANN,
Materials Handling Division
J. L. WALSH,
National Defense Division
L. H. MORRISON,
Oil and Gas Power Division
W. R. ECKART,
Petroleum Division
F. M. GIBSON and W. M. KEENAN,
Power Division
WINFIELD S. HUSON,
Printing Machinery Division
MARION B. RICHARDSON,
Railroad Division
JAMES W. COX, JR.,
Textile Division
WM. BRAID WHITE,
Wood Industries Division

Aeronautics

Motor Life, American and Foreign[1]

A-14 How does the life of the American motor compare with that of the foreign motor in actual flying time (not bench tests)?

A very good indication of the problematical life of an aviation engine is the length of time it can run between overhauls without loss of power or severe wear of parts. To mention a specific engine on which data are available to the writer, the Wright Whirlwind 200-hp. air-cooled engine, reports from many operators in commercial service advise that they have run their Whirlwinds from 250 to 300 hours without overhaul and without loss of power. The builders have received reports from a number of operators who have taken down their engines after from 250 to 300 hours, giving the lists of parts that were replaced, and in many instances the cost of these parts was less than $10 per engine, and the overhaul really constituted only thoroughly cleaning the engine and regrinding the valves.

In comparing the above data with a recent advertisement of the Bristol Airplane Company on 16 Bristol Jupiter engines in the service of K. L. M., it is shown that for these 16 engines the average time between overhauls was 135 hours, and that only eight of them had run 200 hours before they were overhauled. A chart of hourage between overhauls is given, and this indicates that none of them have run materially over 200 hours between overhauls. It is possible, however, that instructions have been issued for engines to be overhauled at 200 hours when perhaps they could have run longer. In normal service, if a Wright Whirlwind is not losing power or oil pressure, the makers are content to have the overhaul period run to 300 hours, provided the engine is given an overhaul once per year.

At the end of 1926 a telegraphic questionnaire was sent to all Whirlwind-engine commercial operators for a report of mileage flown and forced landings due to engine breakage. The reports total 1,750,000 miles flown in the United States and Canada in 1926 by commercial operators, with only three forced landings. It is believed that no aviation engine in the world has such a record of safety. In order to get breakdown tests without too great loss of time, a supercharger to pump air to the carburetor was recently attached to an engine and a duration test run under these conditions. The engine pulled 295 horsepower for 50 hours, an overload of 42 per cent. It is doubtful if any kind of internal-combustion engine, steam engine, or electric motor could stand an overload test of 42 per cent for 50 hours and come through in as good condition as did this stock engine which was so tested. (C. G. Peterson, Assistant to President, Wright Aeronautical Corporation, Paterson, N. J.)

[1] This subject has been discussed in a previous issue.

Fuels

Burning Pulverized Lignite

F-12 Is it advisable to install pulverized-coal equipment in a Texas plant containing five 200-hp. fire-tube boilers when burning lignite coal of 7500 B.t.u. content? Fireman pay is now $2.50 per 12-hr. day, and the average boiler efficiency is 64 per cent. Will the excessive moisture clog the system?

Insufficient figures are given to fully answer the question. If coal costs $10 per ton, pulverized fuel might become a very attractive investment. It seems to the writer that $4 per ton would be the point at which the investment would be justified. This again depends upon the nature of the plant load, the cost of power for pulverizing, and the construction work necessary to rebuild the plant. The high moisture content of lignite will cause no trouble, as it is mostly inherent moisture and has little effect so far as clogging the system is concerned. The writer believes that the 64 per cent given in the question is 10 per cent too high for lignite hand fired with fire-tube boilers. (T. A. Marsh, Western Engineer, Combustion Engineering Corp., Chicago, Ill.)

Machine-Shop Practice

Machining Copper[1]

MS-10 What lubricants and coolants should be used in machining pure copper?

The writer recalls that, in a machine shop in Troy, N. Y., several years ago where considerable difficulty was encountered in an attempt to produce a smooth finish on copper turned in a lathe, the problem was finally solved by using milk as a coolant and lubricant. The milk did not remain pleasant to use, however, so it was necessary to renew the supply every day. Perhaps the chemist has perfected a solution that produces the same result with less of the objections to milk. The writer would be pleased to have further comment on this subject from readers. (Fred J. Miller, New Hope, Bucks Co., Center Bridge, Pa.)

Management

Selling Price During Slack Periods

MG-4 The busy season of a small tool-manufacturing plant extends from January to May, inclusive. June, July, August, and September are rather slack months. The burden is distributed according to the direct labor, a factor of approximately 160 per cent being used. During the summer months competition from smaller shops in the neighborhood is keen, owing to the small overhead of the smaller shops. Is it advisable to make the selling price low enough to sell the tools, even though the books show a loss, according to the factor? If this is not done there will be no summer work and the overhead will be nearly as great.

It is very difficult to give a general answer to this question, as the proper solution of the problem depends almost entirely upon the particular conditions obtaining in the individual plant under consideration. Burden or expense may be classified under two

general headings: fixed and variable. Under normal conditions both should be included in the burden rate and applied to the product turned out. If, under the conditions set forth in the question, there can be obtained business that will return prime cost and variable expense together with any part of the fixed expense, the total loss that would otherwise be taken will be reduced. However, if such work is undertaken at a price which will not return prime cost and all of the variable expense, this loss will be increased. The point the writer wishes to make is that the sales price for extra work during slack periods cannot be safely determined without a clean-cut analysis of expense into the two classes mentioned above. The expense of the plant mentioned should be analyzed in this manner and budgeted over an entire year on the basis of expected production. A safe burden rate should be established for use only in estimating the cost of extra work during the slack season. It might also be wise, on the basis of this study, to increase the regular burden rate used for costing. (G. F. Mellen, Assistant Professor, Department of Industrial Engineering, Pennsylvania State College.)

Railroad

HEAT-TREATED STEEL FOR CARS AND LOCOMOTIVES[1]

R-8 Why is not more heat-treated steel used by railroads in the construction of cars and locomotives?

(*a*) The use of heat-treated, or more properly, "quenched and tempered," steel is justified only when a reduction in weight is desired without diminution of strength. This requirement applies only to certain parts of certain locomotives, and as the application of quenched and tempered steel increases the cost of the locomotive and the cost of maintenance, its use is resorted to only when conditions require it. (Robert S. McConnell, Chief Consulting Engineer, Baldwin Locomotive Works, Philadelphia, Pa.)

(*b*) In the opinion of the writer, this is largely due to conservatism and the expense involved in the use of heat-treated steel. (William Elmer, Special Engineer, Pennsylvania Railroad System, Philadelphia, Pa.)

Textile

LARGE LOOMS[2]

T-10 What is the reed width of the largest loom ever built and what is woven on that loom?

(*a*) With reference to this subject as discussed in the December, 1926, issue of MECHANICAL ENGINEERING, the writer would state that his company has built looms 42 ft. in width for weaving paper felts. Reports have recently appeared in some of the textile magazines of a German loom 70 ft. in width for weaving this type of fabric, but the writer does not know any particulars regarding it. (A. P. Paine, Crompton and Knowles Loom Works, Worcester, Mass.)

(*b*) The largest loom the writer has any knowledge of has, or had when he saw it thirteen years ago, a reed width of 44 ft. and is used for weaving felt. (A. R. Jealous, Assistant Works Manager, The Clark Thread Co., Newark, N. J.)

Wood Industries

MAHOGANY FINISH FOR OAK

WI-1 What types of stains, varnishes, etc. are recommended to produce a reasonably lasting mahogany finish for an oak stair tread?

A mahogany finish, one that will be reasonably lasting, may be obtained by the use of a mahogany floor and furniture stain containing a high-grade varnish and coloring matter. If the wood is new, two coats will be necessary, because the first coat will soak in. The permanency of the finish on the stair tread will depend upon the amount of use to which the tread is put. Constant friction of the shoes will wear away the film. A rubber tread for the walking space is recommended. To make the finish more lasting, apply a paste floor wax and polish to the fullest brilliancy. Occasionally go over the wax surface with a fresh application of liquid wax, but do not use the wax on the stair tread, if it is to be used without the rubber tread. For a quick-drying job, and one might say a more permanent job, a brushing lacquer, which can also be waxed afterward, is recommended. The purpose of the wax is to act as a cushion or protective coating between the shoe and the finished surface. (John M. Lynch, Sales Manager, Sapolin Co., Inc., New York, N. Y.)

[2] This subject has been discussed in a previous issue.

Miscellaneous

BRASS FITTINGS IN WATER LINES

M-1 If city water is allowed to flow through a brass fitting at a very low velocity and small rate of flow, and at a temperature of 90 deg. fahr., will there be any mineral deposits from "hard" water, and will there be any danger of slime or growths of any kind inside the fittings?

(*a*) The character of the water is of basic importance in answering this question. In general, however, there appears to be less tendency for deposits or growths to form in brass pipe than in iron pipe. (F. G. Keyes, Professor of Physico-Chemical Research, Massachusetts Institute of Technology.)

(*b*) With water of high temporary hardness a deposit of calcium carbonate is very likely to appear at a temperature of 90 deg. fahr. Assuming practically settled water from a city supply with any sort of control, there will be no danger of slime or growths inside the fitting. (S. C. Bloom, Consulting Engineer, Chicago, Ill.)

GAS INLETS TO SHELL-AND-TUBE-TYPE AMMONIA CONDENSERS

M-2 In vertical shell-and-tube-type ammonia condensers, what have operation results indicated to be the most desirable point of admission of the gas into the shell?

(*a*) Admission of gas into the center of the shell is considered advisable, as there is a better distribution of gas and more uniform temperature of shell and tubes. Comparative tests with top, bottom, and center admission indicate no advantage for so-called "counterflow" arrangements. (L. S. Morse, Chief Engineer, York Manufacturing Company, York, Pa.)

(*b*) The writer is quite sure that no actual tests have been made to determine where the discharge pipe should enter a shell-and-tube-type ammonia condenser, and in all condensers which he has installed this connection has been placed either in the center of the shell or very close to the bottom. The reason for doing this is to remove entirely the superheat removal period in the condenser. The main advantage is that the temperature differences in the condenser will not vary so greatly with this type of construction as they will if the discharge vapor comes in at the top of the condenser and causes a very hot spot at that point. The writer believes that, taking everything into consideration, in this type of condenser the amount of heat transferred per square foot is greater for the liquefaction period than it is for the superheat period. (Fred Ophuls, President, Ophuls & Hill, Inc., New York, N. Y.)

Questions to Which Answers Are Solicited

RAILROAD

R-9 In checking over the designs of railway elliptical springs it is found that there is disagreement as to the effect of the bands, some considering that it restrains the action of the leaves, and others ignoring it entirely. There is likewise a difference in the modulus of elasticity used, which affects the deflection value of the spring. Another variation is in the length used in determining the characteristics, some using total length and others the net length. Exchange of information with members through this department should prove helpful.

MANAGEMENT

MG-5 What have been the experiences of members of the Society with foremen's bonus, and what is the general basis on which such a bonus is given?

Correspondence

CONTRIBUTIONS to the Correspondence Department of Mechanical Engineering are solicited. Contributions particularly welcomed are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on activities or policies of the Society in Research and Standardization.

A Graphical Study of Journal Lubrication

TO THE EDITOR:

Part III of A Graphical Study of Journal Lubrication[1] showed that *when a journal is supported in a 120-deg. fitted bearing, it will run with considerably less friction than if it were supported by two 60-deg. fitted pivoted segments.* Before making this assertion, the writer estimated the effect of side leakage for such bearings one diameter wide. It was found that the single surface was substantially superior to the subdivided one when the width was one diameter in both cases, whether or not side leakage was taken into account. Michell's analysis was used in estimating the influence of side leakage.

In his discussion of Part III Mr. Newbigin bore lightly on Michell's analysis of side leakage, but quoted experiments in an effort to prove the superiority of the divided pivoted-block surface. The writer's closure showed that Newbigin's test results were indefinite and inconclusive, and that Newbigin made no definite statement of the proportion of bearing width to length beyond which the two pivoted segments would be superior to a single surface of the same width.

Engineering (London), in its notice of Part III published this definite statement in its issue of August 30, 1926:

> Thus if a brass in which this ratio is unity was replaced by two pivoted segmental brasses of equal total area, then, other things being equal, the carrying power would be increased nearly 70 per cent. It would seem, therefore, that the effects of side leakage of oil cannot safely be neglected in theoretical discussions of this kind.

The issue has now been fairly joined. The analyses of Reynolds and Michell are therefore examined below to find where they lead in the design of bearings, and to what extent they solve the problem before us.

"Carrying power," the term employed by *Engineering*, is presumed to mean the ability of a film of standard shape and thickness to carry load. This term requires much qualification and explanation. It is not so readily understood as the simple term "Friction." After all is said and done, bearings should be so designed and constructed that they will run with the least friction that is consistent with a reasonable factor of safety. For this reason film thickness and friction should be very carefully controlled. The carrying power will then take care of itself.

Ten years ago the writer made a careful study of Michell's analysis to see how it compared with experimental results obtained with Kingsbury thrust bearings. Reynolds' analytical work was compared with that of Michell and a correction factor k obtained for Reynolds' simple formulas. This factor k varies with the ratio of bearing length to width, as shown in Fig. 2. It is only approximate because both Reynolds and Michell assume constant viscosity within the oil film, which is usually far from the fact. The factor k in Fig. 2 also applies only to flat bearing surfaces, one of which moves in a straight line with respect to the other.

It is the purpose of this letter to show how far Reynolds' fundamental analysis and Michell's analysis of side leakage can be usefully applied to the design of bearings that consist of pivoted flat surfaces supporting another flat surface that moves in a straight line, *if the viscosity is constant* and no other abnormal condition is present.

Reynolds' equation for the friction force F required to push the loaded plate along, in Fig. 1, may be put in the following form:

$$F = RW\sqrt{\frac{\mu U}{a w}} \quad \ldots\ldots\ldots\ldots\ldots\ldots [1]$$

where F = friction force required to keep the loaded plate in motion with velocity U

k = factor depending on ratio a/b as shown in Fig. 2 (interpreted from Michell's analysis of side leakage)

a = length of plate in direction of motion

b = width of plate

R = constant determined by Reynolds = 1.81

W = weight of the plate and the load it carries

μ = coefficient of viscosity (absolute) of the lubricant

U = speed at which plate is moved by force F

w = specific pressure = W/ab

A = ab = area of plate that rides on the oil film.

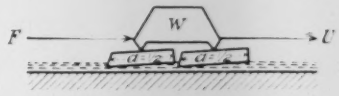


FIG. 1 LOADED PLATE RIDING ON FILM OF OIL
(Length of plate = a; width = b.)

The effect of side leakage upon the friction, as determined by Michell, may be introduced into Reynold's Equation [1] by means

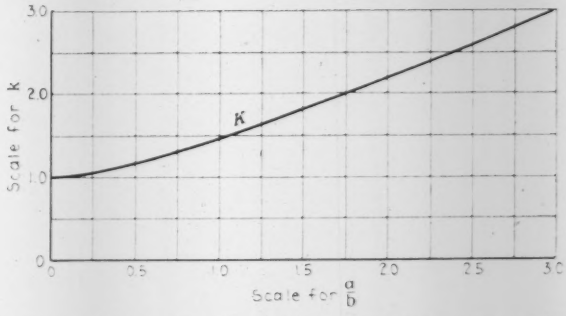


FIG. 2 FRICTION CORRECTION FACTOR k AS INTERPRETED FROM MICHELL'S ANALYSIS OF FLAT BEARING SURFACES

of a factor k, which varies in magnitude with the ratio a/b, as shown by curve K in Fig. 2. The influence of the length a upon the friction is also seen to be important, other things being equal. Hence for the purpose of this study Equation [1] will be rearranged and k introduced, giving Equation [2].

$$F = \frac{k}{\sqrt{a}} RW\sqrt{\frac{\mu U}{w}} \quad \ldots\ldots\ldots\ldots\ldots\ldots [2]$$

It is obvious from Equation [2] that, when studying the influence of the ratio a/b upon the friction F, all other factors must be kept constant, i.e., no change should be made in the load W, the viscosity μ, the speed U, or the specific pressure w. Hence the area $A = ab$ must be fixed. The friction F will then vary with $k/\sqrt{a}$. For the purpose of this study the area A is assumed to be unity, i.e., $ab = 1$.

In Fig. 3 seven surfaces are drawn with equal areas but with different proportions, a/b varying from 2 to $^1/_3$. In all cases $ab = 1$. Each surface may be considered in turn as a single plate, supporting the load W as in Fig. 1. The arrow on each plate represents the direction of motion. For the square surface, $a/b = 1$, it is found that $k/\sqrt{a} = 1.45$. In Table 1 the values of $k/\sqrt{a}$ are shown for a large range of ratios a/b. Curve L in Fig. 4 is a plat of those tabular ratios. The low point on this curve is found to be at X, for which $a/b = 0.6$.

Curves M, N, and P in Fig. 4 show the relative friction of six alternatives, in each of which a certain single plate having an area

[1] H. A. S. Howarth, in Trans. A.S.M.E., vol. 47 (1925), p. 1073.

TABLE 1 CALCULATIONS FOR VARIOUS PROPORTIONS OF A SINGLE PLATE OF CONSTANT AREA $ab = 1$

Item	$\frac{a}{b}$	a	b	k	$\sqrt{a}$	$\frac{k}{\sqrt{a}}$
1	1/3	0.577	1.731	1.09	0.76	1.434
2	1/2	0.707	1.414	1.15	0.841	1.369
3	2/3	0.816	1.225	1.25	0.903	1.385
4	1	1	1	1.45	1	1.45
5	1 1/3	1.155	0.867	1.7	1.075	1.58
6	1 1/2	1.225	0.816	1.82	1.107	1.645
7	2	1.414	0.707	2.18	1.187	1.835

$A = 1$ is replaced by two or by three plates, all having the same width b as the plate they replace, but with the same total area A, so as not to change any other factors in Equation [2]. All the points on curves M, N, and P lie above curve L, i.e., all such combinations have higher friction than the least that is possible by using only a single plate.

Hence the conclusion must be drawn from this study of the analyses of Reynolds and Michell that *with flat bearing surfaces, the stationary one tiltable and the other moving in a straight line, the least friction occurs when the load is carried on a single surface whose length (in direction of motion) is about sixtenths of its width.* This is true, no matter what the load, or the speed, or the viscosity of the lubricant, or the specific pressure.

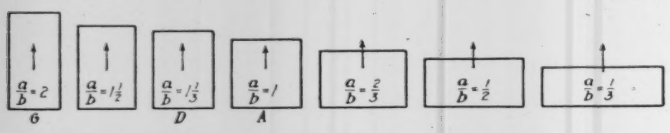
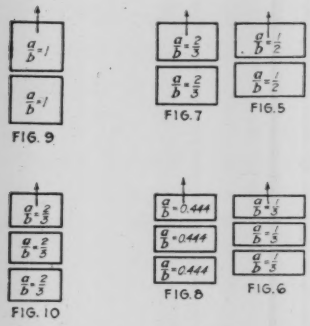


FIG. 3 VISUALIZING VARIOUS PROPORTIONS a/b OF SINGLE PLATES OF CONSTANT AREA $ab = 1$



FIGS. 5–10

It must be remembered that both Reynolds and Michell left out of account the effect of viscosity change within the film, which is very considerable in most bearings. It must also be remembered that these results are not exactly applicable to thrust or to journal bearings, because of different film shapes and pressure distributions. However, the combination of Reynolds' and Michell's work as above interpreted is a long step in the right direction. The resulting Equation [2] needs a smaller percentage of correction than does Reynolds' original Equation [1], in order to check with experimentally determined bearing friction.

In friction Equation [2] the critical-proportions factor $k/\sqrt{a}$ is composed of Michell's k and Reynolds' $1/\sqrt{a}$. In the writer's analysis[2] of journal-bearing friction, Parts I, II, and III, the Reynolds' factor $1/\sqrt{a}$ is fully taken into account. Hence the factor k, as determined by Fig. 2, can be used as an approximate multiplier of the charted coefficients to determine more nearly the actual friction in partial bearings. Its application to full bearings would be of doubtful value.

In view of *Engineering's* statement, quoted above, it is desirable to study Fig. 4 a bit further to learn whether it throws any light on the problem. If a single square plate A in Fig. 3 is replaced by two pivoted plates, of same width and total area, the latter would look like those in Fig. 5, placed for convenience directly under the single plate A which the two replace. In Table 2, item 1, the calculations are found covering this case. Point B on curve P in Fig. 4 is plotted therefrom. The friction for the two 1/2 × 1 plates is 12.4 per cent higher than for the single 1 × 1 plate. It seems, therefore, that *Engineering* must have overlooked the importance of Reynolds' factor $1/\sqrt{a}$ when stating that "the carrying power would be increased nearly 70 per cent."

TABLE 2 CALCULATIONS FOR TWO AND THREE PLATES

Item	$\frac{a}{b}$	a	b	k	$\sqrt{a}$	$\frac{k}{\sqrt{a}}$	No. of plates
1	1/2	1/2	1	1.15	0.707	1.628	2
2	1/3	1/3	1	1.09	0.577	1.89	3
3	2/3	0.577	0.866	1.25	0.76	1.646	2
4	0.444	0.385	0.866	1.13	0.621	1.82	3
5	1	0.707	0.707	1.45	0.841	1.72	2
6	2/3	0.471	0.707	1.25	0.686	1.82	3

[2] Parts I, II, and III of A Graphical Study of Journal Lubrication. Reprinted combined under the title, A Graphical Analysis of Journal Bearing Lubrication.

The question now naturally arises, under what circumstances, if any, would a designer be justified in resorting to the use of two or more plates instead of a single one? Obviously only when faced with length limitations that were serious enough to overbalance increased friction, added complexity, and higher cost.

Putting an arbitrary limitation upon the choice of bearing dimensions, let us suppose that the plate width b must not exceed 0.707 on a scale for which unity would lead to the use of a square plate. Then a single plate like G in Fig. 3 would have the proportions 1.414 × 0.707. The friction factor $k/\sqrt{a}$ for this long, narrow plate would be 1.835. If replaced by two plates, each 0.707 × 0.707, with the same total area, the friction factor $k/\sqrt{a}$ would be 1.72, which is about 6 per cent less than for the single plate G. With the same width limitation of 0.707, the three plates shown in Fig. 10, each 0.471 × 0.707, are seen from Table 2 to have a $k/\sqrt{a}$ factor equal to 1.82. Hence their friction would be about the same as for the single narrow plate G in Fig. 3. Points G, H, and I on curve M in Fig. 4 show the relative friction factors $k/\sqrt{a}$ for one, two, and three plates of same width 0.707 and having a total area of 1.0.

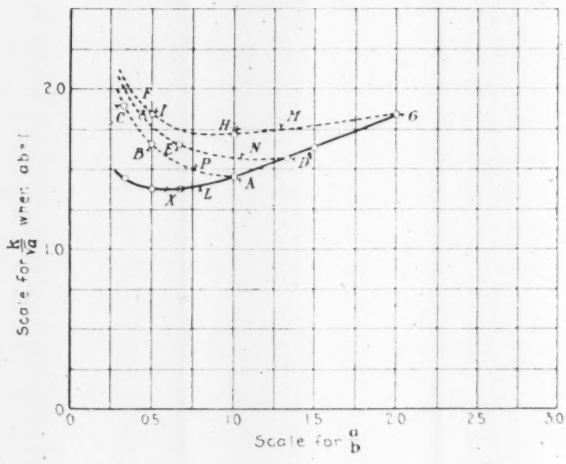


FIG. 4 VARIATIONS IN FRICTION OF PLATES

Curve L for various proportions of single plates
Curve M, Curve N, Curve P for 2 and 3 plates with area equivalent to: Plate G, Plate D, Plate A

Starting next with a single plate whose width is 0.867 and whose length is $a = 1.155$, and replacing this first by two and then by three plates, it will be found that the friction factor $k/\sqrt{a}$ for two plates as in Fig. 7 will be 1.042 times that for the single plate D in Fig. 3. Using three plates as in Fig. 8 the friction factor is 1.152 times that for the single plate D. Curve N in Fig. 4 covers these alternatives.

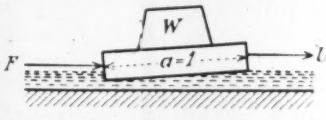


FIG. 11 LOAD CARRIED BY TWO PLATES WHOSE TOTAL LENGTH IS A/b AND WHOSE WIDTH IS b

Examination of the results plotted in the curves M, N, and P of Fig. 4 shows that *when the width limitation prevents the use of a single plate whose proportions are $a/b < 1.5$, two narrower plates may be substituted for the one with some saving in friction. This relative saving of friction increases as the available space for the bearing decreases in width.*

The conclusions to be drawn from this analysis of Reynolds' and Michell's work are that—

1 When space limitations for the bearing do not prevent it, a single surface should be used having a length a about 60 per cent of its width b.

2 When the space is restricted so as not to permit the above ideal proportions, a single surface should still be used, provided the ratio a/b does not exceed 1.5.

3 When the ratio a/b would be as high as 2 for a single surface,

the reduction of friction by dividing the single bearing surface into two pivoted parts is so slight (6 per cent) as to make the added complexity of design of doubtful value. There is no justification for the use of three plates in this case.

4 If the ratio a/b for a single surface must unavoidably be greater than 2, as the ratio a/b for the single surface increases there will first be some justification for subdividing the single surface into two. For still larger values of a/b (not determined), three surfaces or even more might eventually be justified on the ground of friction reduction.

H. A. S. HOWARTH.[3]

Philadelphia, Pa.

A Proposed System of Dimensioning Mechanical Drawings

TO THE EDITOR:

Dimension figures of a drawing should be complete enough to obviate scaling and should be arranged for quick and easy finding.

A common way of dimensioning is to give plenty of dimensions, as in Fig. 1. Here the partial dimensions 2″ and 4″ as well as their sum 6″ are given. This may be called the "duplicating" system. It presents dimensions without search or calculations, the overall also checking the components.

Another way of dimensioning is to give each only once. This

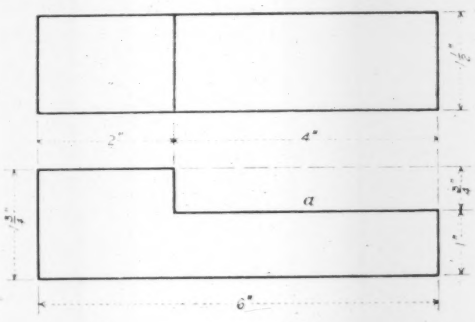


FIG. 1

"only once" system is illustrated in Fig. 2. Here the dimensions 2″ and 3/4″ are omitted. In case they are wanted they can be determined from the given dimensions.

The disadvantages of the "duplicating" system are as follows:

1 It does not indicate to the shopman which dimensions are the most important.

2 If a change of dimension is made on a drawing, a number of other dimensions related to it must also be changed; and it is easy to overlook some related dimensions, and contradictions may occur in the drawing.

3 It fails to indicate from which line and in what order the machinist is to measure.

This last, in the opinion of the writer, is the greatest disadvantage of the duplicating system, because on work where close limits are not called for it often leads to cumulative errors at points where such errors are serious.

The disadvantages of the "only once" system are as follows:

1 It is often difficult to find dimensions which are given on another view.

2 It is still more difficult to get other dimensions which, being given only indirectly, require mathematical calculation.

3 Main dimensions, as overall length, etc., are often missing, though they are very helpful in getting a clear view of the drawing.

4 If one drawing is supplied for several operations, the only dimensions given are for finishing operations. The patternmaker and the smith are naturally interested in other dimensions than those required by the machinist, therefore it is an inconvenience for them to miss much-needed dimensions.

In view of the faults of the generally used dimensioning systems, the writer proposes the general adoption of the "reference dimension" system which has already been used to some extent by the U. S. Navy and elsewhere, and to which he calls the attention of the Society's Special Standardization Committee on Standards for Drawings and Drafting-Room Practice.

This is basically an "only once" system, but the use of additional dimensions is permitted and even encouraged if the extra dimensions are marked as intended for *reference only*. Suggested marks are the letter *r* on the right upper corner or a cross diagonally over the figure. Using this system, the drawing of the key in Fig. 1 would look like Fig. 3.

Under this system there are enough dimensions on the drawing so that any one can find at a glance the one he is looking for. There is no waste of time in calculating dimensions, and proportionately less chance for error. The same dimensions can be placed on several views if the extra ones are marked.

The finishing machinist uses only the main dimensions and ignores the reference dimensions. He will always know from which line to measure, and to which dimensions he has to hold.

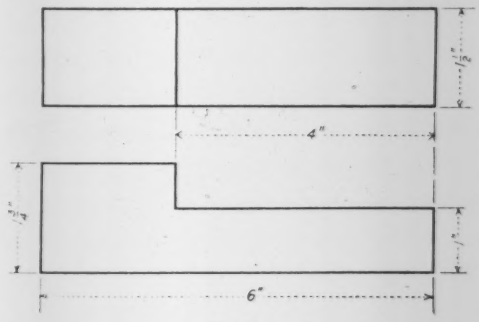


FIG. 2

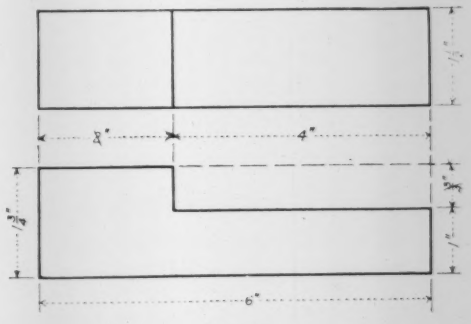


FIG. 3

In changing one dimension on a finished drawing and leaving all other dimensions of the piece unchanged, no mistake can arise, because the changed dimension cannot interfere with the main dimensions. In case of contradiction the respective reference dimensions are to be ignored.

P. H. SCHWEITZER.[4]

State College, Pa.

Sectional Committee at Work on Standards for Drawing and Drafting-Room Practice

UNDER the joint sponsorship of the Society for the Promotion of Engineering Education and The American Society of Mechanical Engineers the Sectional Committee on Standards for Drawings and Drafting-Room Practice was organized on September 24, 1926, with Prof. F. DeR. Furman as Temporary Chairman and C. W. Keuffel as Temporary Secretary. The Committee now consists of forty-four members, representing all interests. Five Sub-Committees have been organized so far, covering the following divisions of the project: Specifications for Paper and Cloth, A. A. Coburn, Temporary Chairman; Method of Indicating Dimensions, G. Schobinger, Temporary Chairman; Lettering, T. G. Crawford, Temporary Chairman; Layout, F. G. Wolff, Temporary Chairman; and Line Work, S. Ketchum, Temporary Chairman. These Sub-Committees are at present at work.

[3] General Manager and Chief Engineer, Kingsbury Machine Works, Inc. Mem. A.S.M.E.

[4] Associate Professor of Engineering Research, Pennsylvania State College.

Engineering and Industrial Standardization

National Standardization Movements in Foreign Countries[1]

BESIDES the United States, there are 20 countries in which national standardizing bodies have been established. These are: Austria, Australia, Belgium, Canada, Czechoslovakia, Denmark, Finland, France, Germany, Great Britain, Holland, Hungary, Italy, Japan, Norway, Peru, Poland, Russia, Sweden, and Switzerland.

With the exception of the British Engineering Standards Association, which was established in 1901, all of these bodies were established during or after the war.

Method of Work. The procedure of all the national bodies is largely based upon the method of coöperation developed by the British, which has come to be technically known as "sectional committee" procedure. The actual formulation of specifications and other forms of industrial standards and the technical decisions involved are in the hands of "sectional committees," each of which is made up primarily of accredited representatives of the various bodies concerned with the standard in question.

The sectional committee is designed to be a true cross-section of all the industrial groups concerned with the standardization work for which it is responsible.

The various interests concerned (producers, distributors, and consumers, including public authorities and independent experts) coöperate in the work.

The American Engineering Standards Committee is the most decentralized of all the national bodies. No other body has the arrangement called "sponsorship," though the Germans have something akin to it in parts of their work.

As a matter of principle, the national bodies generally do not initiate work, but wait for an expression of a desire on the part of the interests concerned that a certain project shall be taken up. Draft standards worked out by the sectional committee are published for criticism in technical and trade papers before being finally approved. In several countries a special journal is issued by the national body.

No difference in procedure is made by the foreign bodies for cases of simplification and standardization; one body handles both.

A trade mark indicating the fact that certain products comply with standard specifications established by the national body has been adopted in several countries, for example, in Czechoslovakia, Germany, and Great Britain.

Financial Support. In the great majority of cases the main support of the national bodies is given by the industries coöperating in the work. German industry provides its national body with more than half a million gold marks ($125,000) annually. The annual support received by the British body from private industries is understood to be about 40,000 pounds sterling($195,000).

When the national body in Czechoslovakia was established by 11 engineering firms, employing about 37,000 workmen, these firms took it upon themselves to keep the work going for three years (1922–1925, inclusive). In 1924 the total support amounted to 600,000 crowns ($25,000).

In addition, the government usually makes a grant in aid, which in several countries amounts to a considerable fraction of the total budget, as in Australia, Great Britain, Canada, and Norway. It is reported that the German Government, which withdrew all support when the mark collapsed, is arranging now to provide a very large sum in support of the work.

Relation to Government. Three national bodies are entirely under control of their respective governments, namely, those in France, Japan, and Russia. The French governmental body was established in 1918 under the aegis of the Ministry of Commerce. It has been inactive since 1923. A new national body of non-governmental character was established in 1926 by powerful associations in the mechanical, metallurgical, and electrical industries.

The governments of the different countries take an active part in the work by having representatives on the Main Committee (except in Great Britain) and on the sectional committees.

Great Britain. In 1925 the B.E.S.A. had 475 sectional committees at work, including 2300 engineers and business men, the work being divided into 12 main subjects covering most of the great industries. In 1924, 58,000 copies of standards were sold. The secretariat has a permanent staff of about 50.

Germany. So far about 1600 standards, most of them dimensional, have been established. Most of them are published in loose-leaf form for convenient direct use in shop and drafting room. More than 100,000 sheets are sold per month.

In case there is no central organization in a certain industrial field, all of the technical work of a sectional committee is directed by the general office of the national body. If there is a central organization—for example, a trade association—the technical work of a sectional committee may be performed in a separate office under the supervision of the trade association or the like. The work of this office is then closely coördinated with that in the central office of the national body. Any standard, however developed, passes through a clearing-house department in order to secure uniformity and coördination between the great number of national standards.

The German body, which originally started its work on purely industrial subjects, having expanded its activities outside this field, has for this reason quite recently changed its name from "Standards Committee of German Industry" to "German Standards Committee."

There are more than 1000 firms in Germany which have made a systematically organized standards department an official part of their administrative organization. In all the great firms this department reports directly to the general management. This has given the German work a momentum and an effectiveness which is perhaps equaled in no other country.

Many of the stronger trade associations maintain engineers in the office of the central body, which has a staff of more than sixty.

Two Methods of Approaching International Standards[2]

INTERNATIONAL coöperation in standardization may be approached from two quite different points of view:

1 International standardization may be considered as a separate movement—apart from the active national standardization movements. From this point of view international standards are set up for the assistance and the guidance of the national bodies in their work, and not for actual use in industrial work and commercial transactions.

2 International coöperation may be viewed as an incident to the national standardization movement. From this point of view, practically the sole purpose of international coöperation is for the effect which such coöperation will have on national standards. Thus an "international standard" may easily become a reality without ever being officially promulgated by an international body, but merely by its actual adoption in use by country after country as their national standard.

Broadly speaking, the first point of view is the one which has been followed by the International Electrotechnical Commission.

[1] Memorandum prepared by the Staff of the American Engineering Standards Committee at the request of the "Committee on Standardization Survey." Issued by the A.E.S.C. as MC 552a.

[2] Memorandum prepared by the Staff of the American Engineering Standards Committee at the request of the "Committee on Standardization Survey." Issued as part of MC 552b by the A.E.S.C.

For example, of the seven standards which have been promulgated during the twenty years of its activity, only one, the "copper standard," is yet in actual use as a basis of commercial transactions (though two of the newer ones may become so used). Nevertheless, the interchanges under the aegis of the commission, the effect of the promulgation of the other six international standards (some of which cover broad fundamentals) as a guide to the national movements, and the by-products of this work have all been of great value to the electrical industries of the world.

Also broadly speaking, the second point of view is the one which the national standardizing bodies have in most part followed in their international contacts.

All of the national bodies have profited greatly by the interchange of information on administrative methods, procedure, and experience. Direct informal coöperation between national bodies has yielded many important technical results; for example:

The German and Swiss bodies got together in 1919 with regard to the standardization of pipe and pipe flanges and fittings, the work in this field being joined later by the Austrian, Belgian, Dutch, and Czechoslovakian bodies. During about seven years more than 100 international technical conferences on this subject were held, and at the present time practical uniformity has been reached.

The standard for radial ball bearings is practically a world standard, thus securing universal interchangeability of this product. (In this the Americans have taken an important part.)

Ten countries have the same national standards for Whitworth and metric coarse threads in the most commonly used sizes. Efforts to reach a compromise between the American national standard thread and the British standard Whitworth thread were made at technical conferences held in 1919 in London, and in 1926 in New York.

The diameters of bolt heads and nuts, controlling wrench sizes, is another item which had been given a good deal of attention internationally. At present most of the continental countries have the same standard. Efforts are being made to arrive at a universal standard by eliminating the differences between the continental, the British, and the American standard sizes.

A coördinated standard system of paper sizes, covering the whole range of paper products from large technical drawings down to a label or stamp, is now in extensive use in more than half a dozen continental countries.

Other fields in which international uniformity has been attained through coöperation of the national standardizing bodies are the shipbuilding and the electrical industries (for example, cables and cable accessories); several subdivisions of the mechanical field (for example, transmission elements, shafting, shafting keys, etc.); preferred numbers.

More than a dozen other examples might be cited in which important results have been attained.

The two points of view as to international standardization, already referred to, were debated at length at the Third Conference of the national standardizing bodies held in New York in 1926. As a result it was unanimously agreed that for the present no attempt at the formal promulgation of "international standards" should be made at first by the new body which it was proposed to set up. It was decided instead that the whole emphasis for the present should be based upon coöperative interchanges designed to bring about greater uniformity between national standards, leaving the formal promulgation of standards internationally to be initiated only after more extensive experience should be acquired.

Uniform Vehicle Laws—A Dream of a Reality[3]

THE first round of the battle for uniform traffic laws, in the interest of safety and comfort for both motorist and pedestrian, ended in victory when a thousand delegates, representing every interest and every corner of the union, unanimously voted "aye" on the motion to endorse the Uniform Vehicle Code at Secretary Hoover's National Conference on Street and Highway Safety in Washington last March.

Since then the second round of the battle has been in progress—"selling" the code to each state. As the legislatures in 44 of the 48 states were to meet in 1927—most of them not to meet again for either two or four years—a vigorous campaign at this time was particularly necessary.

[3] Abstracted from an article which appeared in the first issue of *Public Safety*, a new four-page monthly bulletin now published by the National Safety Council, Chicago, Ill.

Motor-vehicle accidents arise, fundamentally, from our American habit of mind. Only a national effort of will can stop them. There are signs that this will is being aroused. Public officials, educators, civic leaders, and others who find themselves facing the accident problem have come to realize that in it lies one of their chief responsibilities to the public which they serve. Thousands of these individuals and these groups want to do something, but don't know exactly what or how. In this general desire, ready to crystallize into determination and concrete activity, lies the hope for public safety. Only through complete coöperation of all agencies, official, commercial and civic, can the public conscience and the national will be aroused.

In putting forth a new monthly bulletin of "Public Safety" it is the aim of the National Safety Council to bring reliable up-to-date information on public accidents and their prevention to every individual and every organization that desires such information and will use it. Additional information to supplement the brief news items of the Bulletin will be furnished by the Council on request.

The third round of the battle is to be fought in the forty or more legislatures now in session. The result depends entirely on the extent to which the citizens of each state, interested in saving human life, make their voices heard and their influence felt. Now is the crucial time for every civic organization, public official, and private citizen to make sure that the legislators understand the reasons behind the Uniform Vehicle Code and the demand for action from their constituents. In committee tangles and legislative jams the bills with the strongest support survive.

Secretary Hoover has been asked by the National Safety Council to have the National Conference on Street and Highway Safety take immediate steps toward formulating a standard or model city traffic ordinance to supplement the Uniform Vehicle Code. At recent meetings of the Public Safety Advisory Committee and Executive Committee of the Council it was brought out that many cities are now revising their traffic ordinances or considering revision thereof, and consequently a national standard would be very helpful.

An Age of Elimination[4]

IN AN ADDRESS before the National Hardware Association, R. W. Standart, Jr., vice-president and treasurer, Standart Bros. Hardware Co., of Detroit, made the statement that this is an age of elimination. For example, he says:

The General Electric Co. are recommending that their trade handle one type of lamp in six different voltages, as they have found their sales are on these lamps. The Hill Bolt Co. of Detroit have confined their line to three sizes and six lengths of carriage bolts, and the same sizes and lengths of machine bolts. This is their entire output. P. & F. Corbin Company have issued a new catalog and greatly reduced their lines. The same applies to the axe story. After we had reduced our line of tinware to the items which we felt were good sellers, a representative of a tinware company called upon us. We asked his opinion of what we had done and he said: "Who gave you the idea?" We told him it was our own. He seemed very much surprised and said that just the previous week all the tinware manufacturers had met and reduced their lines, following practically the same plan that we had adopted. He said we were absolutely right in what we had done.

We made up a chart which gave us a picture of our stock showing the amount of sales for the year, our stock on hand, price, and manufacturer's name. With this chart as a base, we worked out a plan of disposing of slow-selling lines. Our policy is to confine our buying to the best-known lines, or what we consider the best-known lines. Whenever we put in a new line, we shall "wash out" the old line first. This we failed to do in the past, and it was just another reason for our having too many unnecessary sizes and styles. We found we had duplicated items for about the same price, so we eliminated the slow-selling items, but retained the line as complete as possible.

A Correction

ON PAGE 63 of the January, 1927, issue of MECHANICAL ENGINEERING, Messrs. E. M. Karr, E. B. Nichols, and L. V. Ludy should have been listed as representatives of The American Society of Mechanical Engineers on the Sectional Committee on Transmission Chains and Sprockets instead of as representatives of the A. P. I.

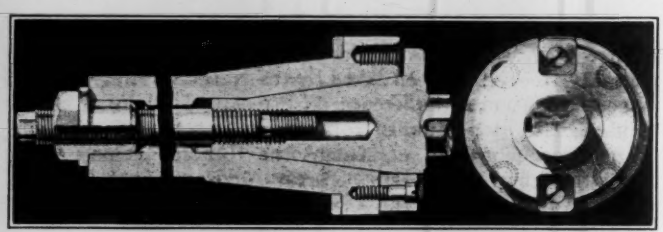
[4] *Monthly News Bulletin* No. 23, National Committee on Metals Utilization.

Milling-Machine Manufacturers Announce Standardized Spindle End

TWENTY-THREE years ago Wm. Lodge, the first president of the National Machine Tool Builders' Association, called attention during the annual meeting of the Association to the great need of a standard for spindle ends—those of milling machines in particular. Up to the time of the last annual meeting of the Association, however, this standardization of milling-machine spindle ends still remained among the important things to be done, and as a matter of fact its accomplishment still appeared to be far in the future.

While many serious attempts had been made by machine-tool builders both in America and in Europe to carry out Mr. Lodge's recommendation, the difficulty of getting concerted effort among a representative group of machine-tool manufacturers made a general standard apparently hopeless. Attempts to improve milling-machine spindle ends were therefore individual efforts and resulted in increasing the assortment of sizes and varieties instead of reducing the number.

When cutters were small and milling machines required but little power to drive them, the conventional taper hole, without draw-in bolts, was all right enough. With the coming of high-speed



SECTIONAL DIAGRAM OF THE NEW MILLING MACHINE SPINDLE END

steel, with the attending growth in size and power of milling machines, there came about a new condition of things which rendered the common style of tapered arbor and end-mill arrangement very unsatisfactory. Sticking of taper shanks in the spindles and loosening at high speeds and feeds may be mentioned as two major difficulties.

The Milling Machine Group of the National Machine Tool Builders' Association has at last succeeded in settling this question by getting together the engineers of the several representative manufacturers, and within a year have worked out a radically different and extremely practical standard milling-machine spindle end. The nine milling-machine builders who coöperated in this effort are adopting this as their standard on machines rated between two and twenty-five horsepower on and after April 1, 1927.

Instead of attempting to make a standard by compromising upon existing devices, this group have courageously scrapped their several designs completely and have started afresh with something entirely new and fundamentally correct from an engineering standpoint. This last important statement has been proved by tests over long periods under extreme conditions.

The standard spindle end and arbor as evolved by the Committee of the Machine Tool Builders' Association is shown in the accompanying diagram. It has a taper of $3\frac{1}{2}$ inches per foot, one that experience has shown will not stick. This taper serves only to accurately locate the arbor. Driving is accomplished by tongues or blocks set in the face of the spindle engaging in slots in the plate on the arbor. A draw-in bolt of large diameter binds the arbor firmly in place. This can be tightened without subjecting the bolt to torsional strains.

The advantages of this new standardized spindle end are obviously many. The sponsors enumerate the following outstanding ones:

1 Complete interchangeability of all arbors and face milling cutters for any size or make of milling machine from two to twenty-five horsepower capacity.

2 Reduction in cost of equipment due to simplification and elimination of the countless sizes and varieties of milling arbors and cutters now in use.

3 New steep-angle taper ($3\frac{1}{2}$ in. per ft.) insures instant release of arbor. The arbor cannot "stick" in the spindle.

4 Inner end of spindle hole is bored straight for arbor pilot, thereby keeping the arbor in place while inserting or removing the draw-in arbor bolt.

5 The steep taper with its large-diameter bore at the outer end of spindle allows the use of stronger arbors, particularly where cutters must be extended.

6 Large-diameter draw-in arbor bolt can be tightened under heavy pressure to firmly hold arbor in taper.

7 Front end of arbor draw-in bolt is provided with an extension threaded end for hold auxiliary equipment.

8 A complete set of new arbors has been adopted, standardized as to diameter, length, keyway, and numbering.

The new series of arbors mentioned in item 8 can be used upon any size of milling machine with the standardized spindle end from two to twenty-five horsepower. Thus tools bought for a No. 1 machine can be used on a No. 5 machine and vice versa. Also, to facilitate ordering, a new uniform system of numbering or nomenclature has been adopted. The three styles of arbors standardized are Style A, Teated Arbors; Style B, Plain Arbors; and Style C, Shell End Mill Arbors.

The bearing sizes are designed thus:

Diameter, inches	No.	For arbors up to and including
$1\frac{7}{8}$	3	$1\frac{1}{4}$ in.
$2\frac{1}{8}$	4	$1\frac{1}{2}$ in.
$2\frac{3}{4}$	5	2 in.
$3\frac{3}{8}$	6	$2\frac{1}{2}$ in.

The arbor symbol is made up of the arbor diameter, style, arbor length (shoulder to nut) and the bearing number, thus:

1A 12 = teated arbor 1 in. diam., 12 in. long.

$1\frac{1}{4}$A 18–4 = teated arbor $1\frac{1}{4}$ in. diam., 18 in. long, with bearing $2\frac{1}{8}$ in. diam.

$1\frac{1}{2}$B 30–5 = plain arbor $1\frac{1}{2}$ in. diam., 30 in. long, with bearings $2\frac{3}{4}$ in. diam.

For metric arbors the symbol is preceded by the letter "M" and the diameter is given in millimeters, thus:

M25B 30–4 = metric arbor 24 mm. diam. style B, 30 in. long, with bearings $2\frac{1}{8}$ in. diam.

Shell end mill or Style C arbors made to accommodate the proposed new standard shell end mills have two variables, the diameter and the distance from the face of the spindle to the back of the cutter. These two variables enter into the symbol thus:

$1\frac{1}{2}$C $\frac{7}{8}$ = shell end mill arbor $1\frac{1}{2}$ in. diam. with a projection of $\frac{7}{8}$ in. from end of spindle to back of end mills.

Keyways in all Style A and Style B arbors have the new standard keyways tentatively adopted by the cutter manufacturers and now in process of standardization by the Milling Cutter Committee under American Engineering Standards Committee procedure. Arbors for shell end mills conform to standards now in the hands of the same committee. While the design of the new standardized spindle end precludes its application to old-style milling machines and thereby likewise precludes the use of the new-style arbors and cutters in the old-style machines, it is entirely possible to use old-style tools in the new-style spindles. This is very important because, while cutters and arbors of the new style will be at once available from the manufacturers, most concerns will desire to "use up" their old tool equipment as far as possible. The use of the old-style equipment in the new spindle is made possible by two types of adapters. One fits into the taper hole of the spindle and is held in place by the draw-in bolt. This is used for end mills and collets with tang drive. The other type, which registers over the outside of the spindle end and is bolted to the spindle face, can be used for arbors, end mills, or other tools having a threaded hole for a draw-in bolt. The auxiliary threaded end on the new standard draw-in bolt serves to hold such tools in place.

Work Completed on T-Slot Standardization

IN PRODUCTION machine shops where jigs, fixtures, and various other holding devices are in general use upon machine-tool beds and tables, the problem of T-slots has long been an extremely vexing one. For fifty years or more it has been apparent to thoughtful engineers that one of the most important steps toward machine-tool interchangeability would be the adoption of standardized T-slots thoughout the industry.

After much agitation of the subject by machine-tool users, builders, the technical press, and various societies and associations, the project was finally undertaken by an A.S.M.E. Sectional Committee on the Standardization of Small Tools and Machine-Tool Elements under the auspices of the American Engineering Standards Committee, with the National Machine Tool Builders' Association, the Society of Automotive Engineers and The American Society of Mechanical Engineers as joint sponsors.

The first Sub-Committee organized under this General Committee was that on T-slots, which held its organization meeting in April, 1924.

After many meetings and a great amount of careful research the Working Committee evolved a standardized series of T-slots, together with T-bolts, T-nuts, cutters, and tongues. The proposed standards were subjected to the usual thorough maker-user consideration and the comments and criticisms thus brought forth resulted in important revisions.

The finished work has now been submitted to the American Engineering Standards Committee under the regular method of procedure, and prompt and complete approval of the new standards has resulted. Details of the new standards appear herewith.

The adoption of these T-slots, bolts, cutters, etc., as the American Standard marks a very important step in machine-tool progress. Any one familiar with the confusion of jigs, fixtures, vises, chucks, etc., in shops equipped with machines with T-slots of various shapes and sizes will realize what vast savings in time and equipment will be obtained under the new system.

While this will do a great deal to simplify matters as far as planers are concerned, it will be even more important in connection with milling machines. Milling machines of various kinds are coming into use more and more in production shops for the rapid cutting of metal, and in almost every case some sort of a holding device bolted to T-slots is an essential part of the set-up. Under the new system such holding devices can be greatly reduced in number and variety, and can themselves be standardized.

This is only a beginning in the matter of machine-tool standardization. Work is already well under way upon such projects as standard tool holders for lathes, planers, etc., spindle noses of lathes, and other details which affect the interchangeability of tooling equipment of production shops.

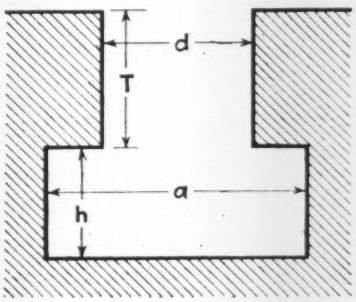


TABLE 1 T-SLOTS—SEE SKETCH ABOVE

Diameter of T-bolt[2]	Width of throat[1,2] (d)	Depth of throat (T) Maximum	Depth of throat (T) Minimum	Head-Space Dimensions and Tolerances — Width (a) Maximum (basic)	Width (a) Tolerance (minus)	Depth (h) Maximum (basic)	Depth (h) Tolerance (minus)	Depth (h) Minimum
1/4	9/32	3/8	1/8	9/16	0.063	1/2	15/64	0.031	13/64
5/16	11/32	7/16	5/32	21/32	0.063	19/32	17/64	0.031	15/64
3/8	7/16	9/16	7/32	25/32	0.063	23/32	21/64	0.031	19/64
1/2	9/16	11/16	5/16	31/32	0.063	29/32	25/64	0.031	23/64
5/8	11/16	7/8	7/16	1 1/4	0.063	1 3/16	31/64	0.031	29/64
3/4	13/16	1 1/16	9/16	1 15/32	0.094	1 3/8	5/8	0.031	19/32
1	1 1/16	1 1/4	3/4	1 27/32	0.094	1 3/4	53/64	0.047	25/32
1 1/4	1 5/16	1 9/16	1	2 7/32	0.094	2 1/8	1 3/32	0.063	1 1/32
1 1/2	1 9/16	1 15/16	1 1/4	2 21/32	0.094	2 9/16	1 11/32	0.063	1 9/32

All dimensions in inches.

[1] A tolerance of minus 0.001 is allowed for "width of throat" when tongues or other parts must fit.

[2] In addition to the "width of throat" given above, a secondary standard is recognized, having the "width of throat" the same as the nominal diameter of the T-bolt. This is to provide for the use, during the transition period, of this standard on many machine tools where it is already established.

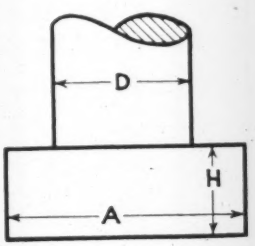


TABLE 2 T-BOLTS—SEE SKETCH ABOVE

Diameter of T bolt[1,2] (D)	Threads per inch[1]	Bolt-Head Dimensions and Tolerances — Width across flats (A) Maximum (basic)	Width across flats (A) Tolerance (minus)	Width across flats (A) Minimum	Width across corners	Height (H) Maximum (basic)	Height (H) Tolerance (minus)	Height (H) Minimum
1/4	20	15/32	0.031	7/16	0.663	5/32	0.016	9/64
5/16	18	9/16	0.031	17/32	0.796	3/16	0.016	11/64
3/8	16	11/16	0.031	21/32	0.972	1/4	0.016	15/64
1/2	13	7/8	0.031	27/32	1.238	5/16	0.016	19/64
5/8	11	1 1/8	0.031	1 3/32	1.591	13/32	0.016	25/64
3/4	10	1 5/16	0.031	1 9/32	1.856	17/32	0.031	1/2
1	8	1 11/16	0.031	1 21/32	2.387	11/16	0.031	21/32
1 1/4	7	2 1/16	0.031	2 1/32	2.917	15/16	0.031	29/32
1 1/2	6	2 1/2	0.031	2 15/32	3.536	1 3/16	0.031	1 5/32

All dimensions in inches.

[1] Tolerances for diameters of bolts or studs and for threads are in accordance with the American (National) Standard Screw Threads, Coarse-Thread series, Medium Fit (Class 3) published by The American Society of Mechanical Engineers, 29 West 39th Street, New York, N. Y. If a free or close-fit thread is desired the tolerances given in the American Standard Screw Threads for either of these classes of fit shall be followed.

[2] T-slots to be used with these bolts will be found in Table 1.

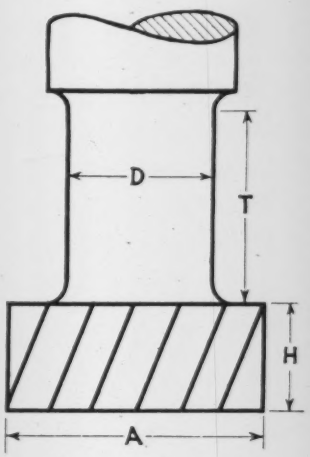


TABLE 3 T-SLOT CUTTERS—SEE SKETCH ABOVE

Width of throat[1,2] Standard	Nominal bolt size	Thickness of cutter (H) Maximum	Thickness of cutter (H) Minimum (worn)	Diameter of cutters (A) Maximum	Diameter of cutters (A) Minimum (worn)	Diameter of neck[2] (D)	Length of neck[2] (T)
9/32	1/4	15/64	13/64	9/16	1/2	17/64	3/8
11/32	5/16	17/64	15/64	21/32	19/32	21/64	7/16
7/16	3/8	21/64	19/64	25/32	23/32	13/32	9/16
9/16	1/2	25/64	23/64	31/32	29/32	17/32	11/16
11/16	5/8	31/64	29/64	1 1/4	1 5/16	21/32	7/8
13/16	3/4	5/8	19/32	1 15/32	1 3/8	25/32	1 1/16
1 1/16	1	53/64	25/32	1 27/32	1 3/4	1 1/32	1 1/4
1 5/16	1 1/4	1 3/32	1 1/32	2 7/32	2 1/8	1 9/32	1 9/16
1 9/16	1 1/2	1 11/32	1 9/32	2 21/32	2 9/16	1 17/32	1 15/16

All dimensions in inches.

[1] The "width of throat" given in the above table corresponds to that given in Table 1 on T-slots.

[2] In addition to the "width of throat" given above, a secondary standard is recognized, having the "width of throat" the same as the nominal diameter of the T-bolt. This is to provide for the use, during the transition period, of this standard on many machine tools where it is already established. If the narrower throat is used, the diameter of neck *D* should be reduced accordingly.

MECHANICAL ENGINEERING

A Monthly Journal Containing a Review of Progress and Attainments in Mechanical Engineering and Related Fields, The Engineering Index (of current engineering literature), together with a Summary of the Activities, Papers and Proceedings of

The American Society of Mechanical Engineers

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Advisers to the State

GOVERNMENT by experts is the ideal of most philosophic Utopias. To have technical problems solved by technical experts whose minds are free from political bias or thoughts of personal gain, who are not influenced by opinions which cannot bear the light of truth, who insist on facts rather than fancies, and who bring sound, unimpassioned reason to their judgments, is an ideal of popular government. Our modern democracies are influenced, in theory at least, by the advice of the experts that are employed to assist in the technical details of government.

Federal, state, and municipal governments have much advice, because they have many bureaus, and all goes well until the advisers of one bureau disagree with those of another.

A falling out of experts, just as does a disputed action under the law, calls for a court of appeal: a court whose authority, even though it may have no legal status, can nevertheless inspire the disputants with the respect which is necessary to make its decision final.

The city of New York, within the past year, has twice appealed to The American Society of Mechanical Engineers to render judgments in cases in which the city's engineers were in dispute. In one case a committee of the Society decided that its Power Test Codes furnished a basis on which the city's engineers could accept or reject a turbine-driven centrifugal pump, whether turbine and pump were tested individually or as a unit. In another case a committee of experts decided that a type of radiator offered to the city for heating its public schools would be the equivalent of the cast-iron radiators called for in the specification.

Such entirely professional services rendered to a community by a society of experts, besides increasing the prestige of the society, are gratefully appreciated by those who seek them because there is no question of prejudice in the minds of those who render the decision.

The services of warriors have always been at the command of states because states make war. The arts of peace are more diverse. The practitioners of these arts develop more broadly in industrial than in civil life, but through their combined efforts in serving on committees of the professional engineering societies, these men are able to render their state a service which it cannot hire. The further its influence is felt, the greater the society will grow.

The Shifting Sands of Verity

THE history of the physical sciences is full of discoveries that things which were throught to be true are not. The original conception of Greek philosophy that the world was made up of earth, water, air, and fire went overboard at a fairly early date. The medieval alchemists who claimed the power to transform base metals into gold were the next to be found to be wanting in truth. Their flimsy theory was replaced around the end of the 18th century by what appeared to be a most solid structure. All things material were now supposed to consist of a limited number of elements, immutable and unchangeable. The transmutation of elements was anathema. At the same time, what was considered to be a vital difference was recognized between inorganic and organic materials, the former being reproducible by synthesis, while the latter could be synthesized only in the laboratory of nature itself under the action of a mysterious "life force," the essence of which lay beyond the domain of physical sciences. Then came Wöhler, Perkins, and Kukele and showed that the so-called organic materials could be synthesized, that living organisms were not essential to their production, and that organic materials had a definite structure, similar in principle to the structure of inorganic materials but differing from it in detail. Thus one of the great tenets of chemistry crashed down, and another one, that of immutability of elements, came down no less noisily with the discovery of radium by the Curies, and the work on the atom of Rayleigh, Rutherford, J. J. Thomson, and the galaxy of their successors.

One of the tenets of the creed of the mechanical engineer has been that perpetual motion is a chimera. This was founded on the theory of conservation of energy, itself a tenet of physics first propounded in the 40's of the 19th century. Obviously, if the so-called law of conservation of energy is right, it is impossible for a machine to run and generate power, as all that a machine can do is to convert one form of energy into another, taking, for example, coal in at one end and delivering it as steam at the other. Now, however, comes the physicist who says that the law of conservation of energy is at best not proved, and, in fact, may be considered to have been put into serious doubt. What, then, about the crank with the perpetual-motion idea?

There is a very great lesson to be learned from all of this. The whole apparently solid structure of engineering is not standing on a rock that will prevail forever but on ever shifting sands of verity, perhaps substantially no better than quicksand. One day our most cherished beliefs of structures may fall to the ground and leave us wondering why we did not see how clumsy and weak they were. We have, for example, huge and expensive steam power plants with monstrous turbines in excess of 200,000 hp. each, but somewhere in laboratories spectacled gentlemen are working on producing power from sunlight by photosynthesis and developing electric batteries with carbon as the consumable element. When they have finished their work one more branch of engineering will have to scrap its old textbooks and write new ones.

That flying in a heavier-than-air machine was impossible was proved mathematically at the beginning of this century. Then the Wright brothers, who did not know that it was impossible, built a machine that flew, and then again it was mathematically proved that about 70 m.p.h. would be the limit of speed in air navigation as the resistance increased with some power of the speed which was either a square or a cube. Speeds of 200 m.p.h. have actually been achieved in flying over distances of hundreds of miles under conditions approximating not racing but actual transportation. Now a new group of developments is being made, such as a carburetor that will prevent backfiring into the gasoline line, a device that prevents stalling, a wing that eliminates nose dives, and vigorous attempts are being made to produce an airplane that will rise, fly, and land without involving any skill on the part of the pilot. When this is done and planes are built of a size to carry not half a dozen but a couple of hundred passengers another revision will become in order, and that is, the revision of passenger traffic by rail over long distances. Twenty hours from New York to Chicago is not bad, but will look rather slow as compared with, say, five hours—"To lunch in New York and be in time for dinner in Chicago," as a future transcontinental air navigation company may come to advertise.

In a way it is rather annoying that even in engineering, verity does not stand solid as the Rock of Gibraltar. From another point of view it is a blessing, as it gives each generation—to all practical purposes, each decade—a chance to shape engineering progress so as to keep pace with the swift flow of modern life. Shifting of the sands of verity means not uncertainty and danger but progress, and nowhere in engineering are these sands of verity so liable to shift and bury those who do not look out as in these United States of ours.

Pennsylvania Registration Law Annulled

THE registration or licensing of engineers is now required by law in 25 states. Some of the statutes have been in force for 19 years. Despite this, there is a great diversity in the views of engineers about the value of the practice of legally certifying engineering qualifications either to the standing of the engineering profession or to the safety of the public. A recent decision of the Supreme Court of Pennsylvania adds a bit of fact to the discussion of this principle.

A group of engineers in Pennsylvania contended that the Pennsylvania licensing law abused the police power of the state and violated the state constitution. This licensing act was passed on May 25, 1921. A test case was carried through the various courts to the Supreme Court of the commonwealth, which rendered its decision on January 24, 1927. By this decision the licensing law was declared unconstitutional. The claim that the police power was abused was not held to be valid, and in setting it aside the Court made the following statement:

> Of course, under what circumstances the safety and welfare of the community would seem to require the protection afforded by a professional registration act is primarily for the legislature to decide, and when that body concludes that engineers—who have to do with the construction of our great bridges, reservoirs and buildings, together with other structures which touch the daily life of all the people—must have their qualifications certified by the State, we can hardly say that such an act is, prima facia, an abuse of the police power; for a mistake made by an engineer in figuring the strain and stress capacity of the various members that enter into many latter-day constructions might lead to such a loss of life as would amount to a public calamity, or in the field of electrical engineering, the wrong location of wires and machinery might result in untold injuries, and, again, the unskilled performance of the duties of a mining engineer might not only lead to the loss of human life, but also to much strife between adjoining owners and to litigation in the courts. But, continuing to treat the act now before us as providing only for the licensing of professional engineers, and admitting that this is within the police power of the State, does the statute violate the Constitution in any material respect?

The Court then discussed the ruling question which dealt with the several exemptions provided in the law. The Court could find no conceivable justification for the exemption of "officers and employees of a corporation engaged in interstate commerce as defined in the Act of Congress entitled 'An Act to regulate commerce,' approved February 4, 1887." The opinion proceeds as follows:

> What reasonable grounds can there be for permitting officers and employees of corporations engaged in interstate commerce to practice the profession of engineering in Pennsylvania without registration, while requiring all officers and engineers of corporations not engaged in interstate commerce to be registered? It will be observed that this does not say that these officers and engineers are exempt merely while engaged in interstate commerce work; on the contrary, they are wholly exempt from registration, and may freely practice the profession of engineering in our state. Moreover, when we come to examine the Act of Congress referred to in the exemption, we find that it does not cover all corporations engaged in interstate commerce, but only certain classes of them. Thus, in order to ascertain what the law of Pennsylvania is, we should be obliged to go to an act of Congress and read it into our own statute.

The Court assumed that the exemptions included in the Act were "inseparable expressions of the legislative will, and, as one, at least, of them is unconstitutional, the whole act falls."

The third attack on the act was on the grounds that it violated the provision of the state constitution that one subject only shall be dealt with in a legislative act. The law in question refers to a "professional engineer" and to a "land surveyor" and treats them as separate subjects of legislation. It treats "thel and surveyor" as distinct from what it calls a "professional engineer," rather than as one following a minor branch of engineering. Thus it sets up two subjects of legislation in one statute. The Court also discussed the contention that the Act included a further separate question when it stipulates that it shall be unlawful for either the commonwealth or any of its political subdivisions to engage in construction work involving engineering unless the plans, specifications, and estimates have been approved by and the construction supervised by a registered professional engineer. The Court stated that it was a question whether this provision is subordinate to the main thought of regulating the practice of engineering and whether it does not constitute a distinct subject of legislation. No ruling was made on this point, however.

A recent bulletin of the Engineers' Club of Philadelphia announced that steps are to be taken to secure immediate action to correct the defects in the law declared unconstitutional.

Post-College Training

AT A RECENT meeting of the Engineering Foundation Board with the presidents, secretaries, and chairmen of the research committees of the four Founder Societies, a very interesting discussion took place regarding the possibilities furnished for the development of young engineering graduates in the profession through participation in technical-society activities. The subject is worthy of serious thought by all men occupied in the multifarious phases of engineering activity today.

The discussion revolved chiefly about the problem of properly introducing engineering-college graduates to workaday life. Fault is often found with them because they revolt at the subordinate work to which they are put in their first positions. Many leaders in industry, coöperating with the leaders of formal education, understand the reasons for this and are attempting with varying degrees of success to find a solution. Too many, however, through lack of understanding, resort to repression, and thus drive from the ranks many able and promising young men.

During the four years of his academic career the student, in an intense and necessarily superficial way, passes through all the phases of mature development. Entering as a freshman with little knowledge of the increased freedom and consequent responsibilities ahead and the breadth of activities he is to engage in, he rapidly develops through the succeeding four years to a position in his senior year of dignity and leadership in his little world. It is no wonder, then, that the shock of being suddenly thrust into the larger sphere of life, which of necessity grants no handicap, causes misunderstanding, revolt, and discouragement. No greater service can be rendered by the older men in business and teaching than that of extending sympathy, guidance, and inspiration to these dazed young graduates with their valuable potential assets.

The activities of our Society offer a splendid medium for this. Interest them in attending local, regional, and semi-annual meetings. Here they will learn of the most up-to-date developments in engineering and be thrown in contact with the energetic leaders in the profession. Nothing could be more instructive or inspiring. Many of you are too busy to properly work up papers for presentation. Turn over to the promising and capable young graduates in your organization the collection and formulation of these data Exploit the energies and enthusiasm of creative youth. You will be amply repaid with their interest and loyalty. In many cases the papers may be profitably presented by the men themselves.

Certain phases of research-committee work also offer opportunities for the development of the young graduate engineer. As graduate students in engineering colleges and as blossoming research engineers in industrial and government laboratories they may be given selected limited tasks in connection with the investigational work of the A.S.M.E. Special Research Committees that may be going on in these laboratories. They may also be helpful in working up reports on this work or in collecting bibliographical material preliminary to it. In certain cases it is quite possible that a young graduate could successfully assist in or entirely carry on the secretarial work of a research committee.

By these means industrial and educational leaders today can do much to "acclimatize" the young engineering graduate to the demands of competitive life, and in saving and developing many useful men for service in the engineering profession. Such action would be splendid contribution to the growth and prestige of the profession and of our Society. It will take time, wisdom, and persistence, but it is well worth doing.

T-Slots and Spindle Ends

AMERICAN Standard T-Slots, adopted by the American Engineering Standards Committee, and the new design of milling-machine spindle end, adopted by a group of nine milling-machine manufacturers, are announced simultaneously in this issue of MECHANICAL ENGINEERING and in the technical press of the country. These standards have been advocated many times, their needs pointed out, and the resulting benefits emphasized. The T-Slot Standard is the first American standard machine-tool element, and as such blazes the way for a series of standards which should result in worth-while economies to the machine-tool-using industries of the nation. The spindle end is not a standard in the true sense but an outstanding improvement in design, developed coöperatively and adopted jointly by nine manufacturers. Its effect will be far-reaching, for by its advent all milling machines in use on April 1 are rendered obsolete.

What is the meaning of the phrase "An American Standard" as applied to engineering matters? In general it means that the standard has been arrived at by a procedure that will insure its maximum value and its widespread adoption. As the T-Slot Standard is the first machine-tool element to be standardized under the American Engineering Standards Committee procedure, it will perhaps be well to review in brief what that procedure means. The first tenet of the A.E.S.C. procedure is that the committees dealing with standards of a commercial character shall be made up of producers, consumers, and general interests, and, in cases in which the work is of importance to them, of distributers. Not one of these groups may form a majority except with the recorded consent of the others. The other principles provide broad publicity, resulting in full discussion and criticism.

To illustrate the principles, let us follow the steps taken in establishing the T-Slot Standard. The Sub-Committee on T-Slots was organized in April, 1924, as a sub-committee of the Sectional Committee on Small Tools and Machine-Tool Elements, the sponsors of which were the Society of Automotive Engineers, the National Machine Tool Builders Association, and The American Society of Mechanical Engineers. The first draft of the Standard was ready in December, 1925. This draft was based on data received in reply to a questionnaire broadly distributed in October, 1924. Tests of the strength of T-slots in cast iron were needed, and these were made early in 1925. During June, 1926, the proposed standard was distributed in proof form to a long list of manufacturers and users of machine tools. The criticisms received prompted a revision dated September, 1926. In that form the proposed Standard was approved by the Sub-Committee of the Sectional Committee, and on November 4 the proposed standard was presented to the three sponsor bodies for approval. The last of the three sponsors reported its approval on March 8. It was then submitted to the A.E.S.C. for approval.

The procedure followed in the development and adoption of this American Standard T-slot gave opportunity for a meeting of minds during the preparation process, and the submission of drafts to numerous users for criticism aroused their interest. The net result is that when the standard is completed the using world is prepared for its advent and is looking forward to the economies which its use will make possible.

The new type of milling-machine spindle end is the product of a splendid spirit of coöperation among the engineers engaged in the design of milling machines. A group of manufacturers reviewed the present state of the art and decided that an improvement in design was in order. The new product does not include any elements of existing types of spindle end. The engineers of the various milling-machine companies pooled their experience and knowledge and conducted exhaustive tests, with the result that the new spindle end is a product of the best engineering skill. Its advantages are both in the reduction of cost of maintenance and increased interchangeability. This spindle end as evolved will be the only type of spindle end supplied on machines rated between 2 and 25 hp. on and after April 1, 1927. Provisions have been made for a rather simple means of using the old type of arbors and tools in the new type of spindle. Presumably the users of milling-machines may be under some inconvenience during the early months of the use of the new spindle end. However, it is expected that the advantages to be gained in the long run will commend it.

An interesting by-product of the new spindle design is the fact that it makes use of a $3^1/_2$-inch-per-foot taper for locating purposes only. This removes the need for small-angle tapers in milling machines and simplifies the next steps in standardizing tapers.

Engineering a Modern Element of General Education

AT ALL TIMES there have been certain things, lacking knowledge of which no man would be considered educated. In the Middle Ages such an essential element of education was theology. Religion then played an extremely important part in the government and in every one's life, the church was the possessor of enormous properties, and church law was superior to state law when the two came in contact. Hence, no man could be successful in politics or business without a thorough grounding in theological fundamentals.

In the 18th century and the first half of the 19th the classics took the place of theology. With the growing importance of science, beginning, say, in the 40's of the last century, physics and chemistry—in a very elementary form, it is true—came to be looked upon as sciences indispensable to the mental equipment of an educated man. The violent controversies about Plutonism and Unitarianism in the history of our planet, the germ theory and spontaneous generation of microbes as affecting sanitation and the propagation of diseases. Darwinism or the permanence of species, etc., began to agitate not only scientific circles but general society down to labor groups, and of course no man could comprehend these questions without at least a bowing acquaintance with the fundamentals of such natural sciences as physics, chemistry, and biology.

A fact that may be worth our attention is that while within the last 25 years interest has shifted to engineering problems, there has been no corresponding change in the curricula of general education. It is true that schools for engineering specialists have multiplied enormously, but the teaching in general schools is still carried on in the spirit of the period between 1865 and the end of the Victorian era.

The average family today is mechanized to an extent that would have seemed unbelievable 25 years ago. It drives its own locomotive, even if it calls it a motor car. It listens to music through a complicated and delicately adjusted electrical device called radio. The lady of the house does her sewing and sweeping by electrical machinery and is beginning to electrify her ice box, with the electrification of the kitchen looming as a not-distant possibility. Further, electricity is doing away with the chore of dish washing, while the clothes-washing machine is so familiar as to have become a commonplace.

Out of the 15,000,000 employed in gainful occupations in the United States, probably more than two-thirds work in industries entirely dependent for their existence on modern engineering developments. Engineering has therefore become a permanent part of the warp and woof of the texture of modern life. And yet the schools of today pay no attention to the problem of supplying modern youth with the fundamentals of engineering knowledge. This matter is of more than passing or theoretical interest to mechanical engineers, because there is good reason to believe that it tends to switch into other professions boys who might make good mechanical engineers. Dr. G. T. Morgan, presiding recently at the annual dinner of the British Association of Chemists, pointed out that of scientific subjects only chemistry, physics, and mathematics were taught children. As a result the majority of these of scientific tastes who received higher education became either chemists or physicists. If engineering were taught in at least the same elementary way that physics and chemistry are, more boys would have a chance to find themselves and develop such mechanical gifts as nature has endowed them with.

A Correction

ON PAGE 269 of the March issue, the fifth line from the bottom of the page in the right-hand column should have read as follows: "the former, two 45,000-kw. tandem-compound units with single flow."

The Railway Centennials

WE ARE now in the midst of the centennial period of the first American Railway. Several great systems which have grown out of the pioneer lines have either lately rounded out their first hundred years of corporate existence or are soon to do so. These transportation companies, which have earned the right to be called venerable institutions, are making much of their centennial dates. The public, by showing an awakening interest in railway history and in the centennial celebrations, indicates a growing appreciation of what railways have meant to America in the past and of the important place which they hold in American life today.

During the first thirty years of the 19th century, what may mildly be called keen rivalry developed between water transportation—both canal and steamboat—and steam transportation by rail.

When the smoke produced by many heated arguments finally cleared away it was discovered that neither water transportation nor rail transportation was supreme. Each had its place, and coördination between the two forms eventually came about. As a matter of fact, some of the centennial railways came into being as combination water and rail transportation companies.

It is a peculiar instance of history repeating itself that during the first three decades of the 20th century motor transportation arose to challenge rail transportation much as rail transportation challenged water transportation at a corresponding period of the 19th century. After a period of almost bitter rivalry, aggravated by the serious disorganization resulting from the World War, the smoke is again clearing away. This time it is apparent that neither railway nor automotive transportation is supreme. Instead there is revealed a condition of interdependence—a marked tendency toward coördination between the two systems—which augurs well for both.

In the industrial changes since the war, the railways have had their full share. However, painful this upheaval may have been, it was not without its benefits. There have emerged many railway companies purged of unprofitable auxiliaries and traditional forms of waste, and in many instances strengthened by consolidations based upon sound economic considerations rather than upon the whims of high finance.

Under the new order of things the railway companies are no longer depending upon energetic men having few educational advantages to struggle up from the bottom to high engineering and managerial positions. Instead they are holding forth to energetic college-trained men the splendid opportunities in the railway field and are finding such trained men of great value.

It was the privilege of the last surviving signer of the Declaration of Independence to live long enough to lay the corner stone of a railway system which will celebrate its hundredth birthday on the coming Fourth of July. That venerable man saw more clearly than many of his younger contemporaries the vital part which railways would play in the upbuilding of the Republic of which he was a founder. He was moved to predict things which were doubted by men of his time, but which the passage of the years has more than justified.

Chemistry as a Career

SPEAKING at the annual general meeting of the Institute of Chemistry, Professor G. G. Henerson, president of the Institute, remarked that there appeared to be some abatement of the enthusiasm for chemistry as a career, which was noted immediately after the war. It had not been the policy of the Institute, he said, to adjust the stringency of its regulations and examinations on any principle of supply and demand, but rather to indicate to those who believed that they had a bent for the science that it did not necessarily lead to fortune, that it called for hard work and sacrifices, and that, since the supply of chemists at present exceeded the demand, more than average ability was required for even moderate success. The industries of the country did not sufficiently absorb the scientific talent supplied by the universities, and it was to be deplored that many graduates had to turn to callings which had no direct relations to their technical education.—*The Engineer*, vol. 143, no. 3712, March 4, 1927, p. 229.

Allan Stirling Dies

ALLAN Stirling, noted boiler inventor and one of the original members of the A.S.M.E., died on February 3, 1927, at his home in Norfolk, Va. His death was due to the infirmities of old age.

Mr. Stirling was born on July 25, 1844, at Rutherglen, Scotland. He began his education in the public schools of his native village and later attended the High School of Glasgow. In 1860 he came to America and completed his education at the Cooper Institute in New York. He received the degree of B. S. in M.E.

In the meantime he was employed at the DeLamater Iron Works in New York, having been given a position there as draftsman through the recommendation of John Baird, chief engineer of the Cromwell Line. His first work was to make the drawings of the new DeLamater offices on Thirteenth Street, and later to superintend the removal of the drafting room from the old office on West Street to the new headquarters.

In 1862, Mr. Stirling entered the emergency drafting office which the Navy Department established at Broadway and Franklin Streets, near the home of Capt. John Ericsson, where improved designs for monitors were being worked out. The young engineer was assigned to the design of the blowing engines which supplied air below decks and also worked out plans for gun carriages used in the turrets.

When this Government office was closed at the end of the Civil War, Mr. Stirling spent a year in the machine shop of Anderson & McLaren on Horatio Street in New York in order to gain practical shop experience. At the end of that year he became a draftsman for the firm of Winslow, Griswold & Holley, in Troy, N. Y., in connection with the construction of the first bessemer steel works erected in the United States.

When this task had been completed, Mr. Stirling remained in Troy as draftsman and superintending engineer for the Burden Iron Works. He remained with that concern for eleven years, leaving them in 1878 to take charge of the mechanical department of the Metropolitan Elevated Railway in New York. After the consolidation of this road with the New York Elevated Railway, he continued the same position with the latter organization, and renewed his associations with Mr. DeLamater, much of the railways repair work being done at his shops.

In 1880, Mr. Stirling left the Elevated with the intention of becoming an engineering specialist. After studying the possibilities of various branches (including the new field of electric power), he finally selected that of the steam boiler as offering the best possibilities. In the meantime he designed and built for the Rathbun Company, at Deseronto, Ont., one of the earliest cable conveyors, and also laid out a foundry and machine shop for Coxe Bros., at Drifton, Pa.

In 1883, Mr. Stirling interested his old friend Mr. DeLamater in a unique boiler which he had designed for a working pressure of 300 lb. per sq. in. One was built and operated at the DeLamater Iron Works, but proved to be somewhat "ahead of its" time and the design was given up.

Following this experiment Mr. Stirling served for a year as mechanical engineer for the Otis Elevator Company. Next he again became consulting engineer for the Rathbun Company upon plant improvements, and in carrying out this work he installed boilers of his new design with certain refinements. The success of these led him to establish himself in the boiler business in Canada. The design of the "Three-Drum Stirling" boiler came into his mind during a night ride on a Canadian train. This resulted in the well-known "Four-Drum Stirling" patented by him in 1892, for the manufacture of which the International Boiler Company was established.

Mr. Stirling retired from active business several years ago but still kept up his interest in the boiler business by designing an occasional boiler for an old customer and seeing that a supply of repair parts was maintained.

At the invitation of the late Alexander Holley, Mr. Stirling joined the A.S.M.E. at its inception in 1880 and presented a paper on steam boilers at its first meeting. He served as manager from 1881–1884 and as vice-president from 1885–1887. He was a life member of the Society.

Book Reviews and Library Notes

THE Library is a coöperative activity of the A.S.C.E., the A.I.M.E., the A.S.M.E. and the A.I.E.E. It is administered by the United Engineering Society as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West 39th St., New York, N. Y. In order to place its resources at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references on engineering subjects, copies of translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

A.S.T.M. Tentative Standards—1926

A.S.T.M. TENTATIVE STANDARDS—1926. American Society for Testing Materials, Philadelphia. 1926. 6 × 9 in., 1100 pp. Cloth, $8.50; paper, $7.50.

ELEVEN hundred pages of standards and material specifications are presented in the 1926 Tentative Standards of the American Society for Testing Materials. Some of these standards are entirely new and are published as tentative for the first time. Others are duly approved standards which are republished in connection with tentative revisions. There are 327 tentative standards in the volume, classified according to the nature of materials covered as follows:

Steel, Ferro-Alloys, and Wrought Iron	33
Non-Ferrous Metals	20
Cement, Lime, Gypsum, and Clay Products	22
Preservative Coatings	15
Petroleum Products and Lubricants	22
Road Materials	49
Coal and Coke	2
Timber	6
Waterproofing	16
Insulating Materials	11
Shipping Containers	4
Rubber Products	3
Textile Materials	10
Slate	3
Miscellaneous	11

The following explanation is offered regarding the distinction between "Standards" and "Tentative Standards." The term "Tentative Standard" as distinguished from "Standard" is applied to a proposed standard which is printed for one or more years with a view to eliciting criticism, of which the committee concerned will take due cognizance before recommending final action toward the adoption of such tentative standards by formal action of the society.

In order to bring out the true significance and value of these standards to the engineer, a word as to how they originate and are prepared may not be amiss. Suppose, for instance, that there is a demand for a certain steel product for which no satisfactory specification exists. Some individual, group, engineering society, or other body calls to the attention of the A.S.T.M. the need for an adequate specification covering this product. The A.S.T.M. then refers this request to the proper general committee, which in this case would be Committee A1 on Steel, with a request that the desired specification be prepared. Committee A1 then refers the detail work of preparing the specification to one of its subcommittees which has had experience along similar lines. If the proper sub-committee is not already in existence, one with properly qualified personnel is then appointed. A fundamental policy of the A.S.T.M. is to appoint men experienced along the lines of the work covered on each committee, and to maintain on the committee as even a balance as possible between producers and consumers of that particular material. Consequently the practical experience of both vendor and purchaser is applied to produce a coördinated standard which is intended to adequately protect the best interests of each party. Very frequently certain problems connected with the manufacture or application of a given material are not fully understood by one interest or the other until the matter is thoroughly thrashed out in the committee. As a result, these A.S.T.M. Standards usually have a broader perspective and are more comprehensive than if prepared from the viewpoint of one interest alone. The policy mentioned in a preceding paragraph of having the standards remain tentative and easily subject to revision for one or more years, is an excellent feature which allows individuals or interests not represented on the committee to call attention to inconsistencies or objectionable features. At the same time it gives the committee a chance to amend its own action in the light of subsequent knowledge or sober second thought.

It frequently happens that when a purchaser is applying these specifications he notes where there is a choice of method or practice allowed, or that his particular application demands some requirement not found in a general specification. If such is the case it is very easy for him to prepare a supplementary specification giving his special requirements, and stating that in other respects the material shall conform to A.S.T.M. Specification of such a number. This not only saves the extra work of preparing a complete specification, but in many cases makes it possible to use a standard article instead of special material. The advantage of such an arrangement is obvious.

This volume of Tentative Standards will be of especial interest to those who have occasion to manufacture or use the materials in question. If not in the immediate market for any of the materials dealt with, it is still worth while to examine the standards while they still remain tentative, with a view to calling attention to any features which seem to warrant change or further consideration. The A.S.T.M. organization always welcomes advice of this nature as it tends to broaden the application of its standards.

Among the interests which the standards in this volume concern are power plants, railroads, shipping, structural steel, oil, textiles, miscellaneous machinery, highways, building, paint and other protective coatings, waterproofing, fuel, rubber, automobiles, insulation, shipping containers, etc.

There are three specifications published in this volume which deal with materials for high-pressure and high-temperature piping service in power plants. These specifications were developed for use in connection with the A.E.S.C. Steel Flange Standards for 250, 400, 600, 900, and 1350 Pounds Working Steam Pressure and Temperatures up to 750 deg. fahr. The titles of these Specifications will serve to indicate the particular material covered:

A 95–26 T Carbon-Steel Castings for Valves, Flanges, and Fittings for High-Temperature Service
A 106–26 T Forged or Rolled Steel Pipe Flanges for High-Temperature Service
A 106–26 T Lap-Welded and Seamless Steel Pipe for High-Temperature Service.

There is a similar specification A 96–26 for Alloy-Steel Bolting Material for High-Temperature Service which has already been advanced to "Standard" and hence is not republished in the 1926 Tentative Standards. This set of four specifications gives a reasonably complete selection of piping materials for temperatures up to 750 deg. fahr. for use in steam power plants and oil-refinery work. At the present time the oil people are using these materials at considerably higher temperatures, but 750 deg. fahr.

probably represents the upper limit in power-plant practice until suitable materials are developed for still higher temperatures.

The demand for materials suitable for temperatures above 750 deg. fahr. has led the A.S.T.M. to undertake an active study of the subject. There is, at present, a so-called "High Temperature" committee investigating the general phases of the effect of high temperatures on metals. The sub-committee which prepared the above-mentioned specifications for piping materials for high-temperature service has been asked to prepare another set for service at 1000 deg. fahr. and still another for even higher temperatures. Several of the large concerns represented on these committees have undertaken elaborate investigations regarding the properties of metals up to temperatures as high as 1400 deg. fahr. in some cases. This work has not progressed to the point where it could be reported on in the 1926 Tentative Standards, but it will be of general interest to know that it is under way.

SABIN CROCKER.[1]

Industrial Safety Organization

INDUSTRIAL SAFETY ORGANIZATION FOR EXECUTIVE AND ENGINEER. By Lewis A. DeBlois. McGraw-Hill Book Co., New York, 1926. Cloth, 6 × 9 in., 328 pp., illus., tables, $4.

THIS volume presents the industrial-safety movement as a science, a distinct and desirable departure from the usual safety literature. It describes sound fundamental methods of procedure, drawn from the author's intelligent and full reservoir of knowledge of safety practices. It is not a scrap-book or a collection of safety practices. It is an orderly presentation of the subject in an interesting and constructive contribution.

The twenty-three chapters are arranged in logical sequence, each a concise and complete treatise upon the chapter subject. It is not cluttered with fixed rules and regulations of this or that enthusiast. The author has advantageously omitted such details from his volume, but has provided, in an appendix, ample reference to specific codes or detail practices.

The author briefly states in his first chapter the industrial-accident situation and national and group experience, proceeding to chapter two to illustrate the accomplishments of industrial safety. In chapter three we find following logically the fundamental requirements of industrial safety, and from here on throughout the volume is presented the method of procedure for establishing a fundamentally sound and effective industrial-safety movement.

The closing chapters correlate the safety movement with production and human relations in a very admirable way. The appendix supplies all necessary details of safety practice—specific examples as applied under the author's supervision at the E. I. DuPont DeNemours and Company and in his official capacity with several safety organizations.

This volume is sincerely recommended as a textbook for those desiring to establish an industrial-safety organization, or for those who have been longer associated with the industrial-safety movement and desire to bring their practices into line with scientifically sound fundamental conceptions of the practices and requirements of the industrial-safety movement.

The volume is well printed and well arranged for easy reading with suitable chapter headings and paragraph captions to facilitate quick reference, all supported by an ample index. It is unusual to find a volume which the reviewer can so sincerely recommend in all respects. The rational treatment of the subject is of more than usual merit.

ROBERT D. NEWCOMB.[2]

Book Received in the Library

PATENTS: What a Business Executive Should Know about Patents. By Roger Sherman Hoar. Ronald Press Co., New York, 1926. Cloth, 6 × 9 in., 232 pp., $4.50.

The author is at the head of the patent department of a large manufacturing concern. He attempts in this book to present those portions of the law and practice of patents which are of direct interest to executives, in language devoid of legal terminology. The subject is patent tactics rather than patent law.

PYROXYLIN ENAMELS AND LACQUERS. By Samuel P. Wilson. D. Van Nostrand Co., New York, 1926. Cloth, 6 × 9 in., 213 pp., illus., $3.

A concise description of present practice in lacquers and enamels. The author discusses the raw materials used, the methods of manufacturing lacquers and enamels for leather, wood and metal, and the methods of applying the solutions. A number of tested formulas are given.

REGELUNG UND AUSGLEICH IN DAMPFANLAGEN. By Theodor Stein. Julius Springer, Berlin, 1926. Cloth, 6 × 9 in., 389 pp., illus., diagrams, 30 r.m.

This book discusses, in thorough, systematic fashion, the theory and practice of steam power-plant regulation to meet varying loads. It aims to give the power-plant manager a systematic survey of the apparatus available for the automatic control of the pressure in the steam line and of the firing, and to show how it can be advantageously used. The influence of variations in load upon steam consumption and boiler plants is also discussed.

SCHLEUDERGEBLÄSE, BERECHNUNG UND KONSTRUCKION. By Hans Rudolf Karg. R. Oldenbourg, Munich and Berlin, 1926. Paper, 7 × 10 in., 128 pp., illus., diagrams, 7.50 r.m.

The scanty literature of centrifugal fans is largely descriptive and empirical, and there is a lack of books which provide a student with a systematic exposition of the scientific principles that underlie these machines, and of the application of these principles in construction. This handbook aims to present the physical laws of ventilating fans, so far as they are necessary for designing centrifugal fans, and to describe the design and construction of the latter in sizes up to 60 in. blade diameter and to the highest pressures attainable.

SHOP HINTS ON LOCOMOTIVE VALVE SETTING. By Jack Britton. Second edition. Simmons-Boardman Publishing Co., New York, 1926. Fabrikoid, 5 × 8 in., 350 pp., illus., diagrams, $3.

This book explains the theory of the locomotive valve gears in use, describes the details of their construction, and tells how to set them. The author is a practical valve setter, and the book is planned for use in erecting and repair shops.

SOLVING SEWAGE PROBLEMS. By George W. Fuller and James R. McClintock. McGraw-Hill Book Co., New York, 1926. Cloth, 6 × 9 in., 548 pp., illus., diagrams, tables, $6.

Aims to set forth concisely the fundamental principles of sewage disposal. Brief reference only is made to the old processes that are adequately described in other books, while recent developments in theory and practice are stressed and sufficient details of new plants are given to indicate recent advances in the art. Particular consideration is given to natural purification of streams, basic design data, plain sedimentation tanks, sludge-digestion processes, separate sludge-digestion tanks, collection and utilization of gas, screens, trickling filters, the activated-sludge process, and industrial wastes. Attention is also paid to the legal, legislative, and administrative aspects of the problems.

STEREOSCOPIC PHOTOGRAPHY. By Arthur W. Judge. American Photographic Publishing Co., Boston, 1926. Cloth, 6 × 10 in., 240 pp., illus., diagrams, tables, $5.

A good introduction to the subject and a welcome addition to the scanty literature. The various methods of stereoscopic photography are described and practical advice is given on cameras, processes, stereoscopes, etc. The applications of stereoscopy to microscopy, astronomy, radiography, aerial photography, and other fields are discussed.

TEXTBOOK OF MECHANICS. By E. H. Wood. John Wiley & Sons, New York, 1926. Cloth, 6 × 9 in., 251 pp., $3.

The author has attempted to present the essentials of mechanics

[1] Designing Engineer, Detroit Edison Co., Detroit, Mich. Mem. A.S.M.E.

[2] Superintendent, Deane Works, Worthington Pump & Machinery Corp., Holyoke, Mass. Mem. A.S.M.E.